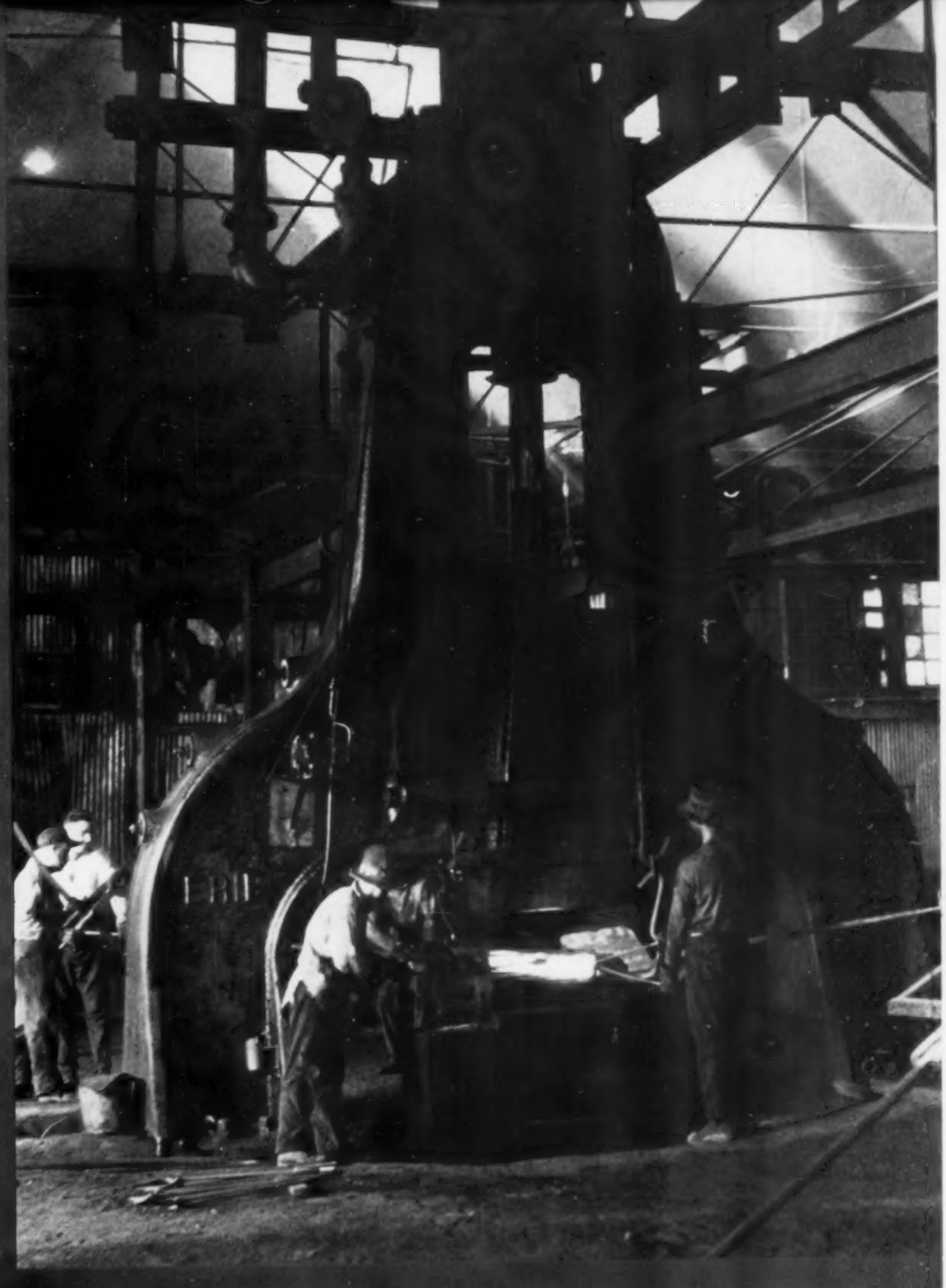


METAL PROGRESS

JULY 1932

2350° WAS THE DANGER MARK!

SUPPOSE you were a drop forger with years of experience in all types of automotive forgings. And suddenly you ran into serious trouble — upset forgings breaking badly on the inside. What would you do?

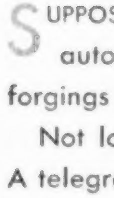
Not long ago a well-known drop forger encountered just this problem. A telegram to Republic . . . and the next morning three Republic Metallurgists checked in the plant, donned overalls and went to work.

Hour upon hour these denim-clad metallurgists — practical drop forgers, all of them — stood at the hammers. Apparently the forging practice was all right. Likewise, heat-treating practice seemed O. K. But these men were there to find the trouble.

Selected bar stock was heated and worked at various temperatures — with the aid of optical pyrometers. At 2200°, 2250°, 2300°, the stock forged perfectly. At 2350° and 2400° things began to happen — breakage occurred.

Another job whipped! Forged at 2250° to 2300°, breakage disappeared.

A few days more — just to make sure the job was really whipped — and Republic Metallurgists moved on to the plant of an automobile manufacturer who was having trouble determining the right roller steel for a free-wheeling unit — but that's another story.



Data of help to every buyer and user of alloy steels is contained in the new edition of the Agathon Alloy Steels Handbook. Write for a copy.

REPUBLIC STEEL
CORPORATION

July, 1932
Volume 22, No. 1

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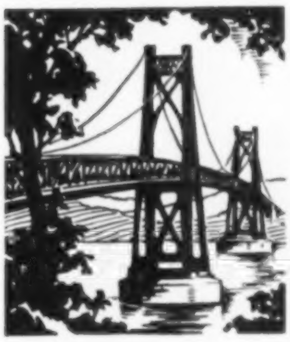
Ernest E. Thum, Editor

Metal Progress

table of contents



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About the authors in this issue


F. W. Cederleaf


W. E. Sanders


Charles Hardy


J. B. Nealey


B. F. Shepherd


A. M. Portevin

METAL PROGRESS is indebted to Ludlum Steel Co. for the inspiration and much of the material used on this month's cover. The photograph is one of a series taken for Ludlum by Miss Margaret Bourke-White, and the layout is an adaptation of a very attractive brochure of photographs issued by the company.

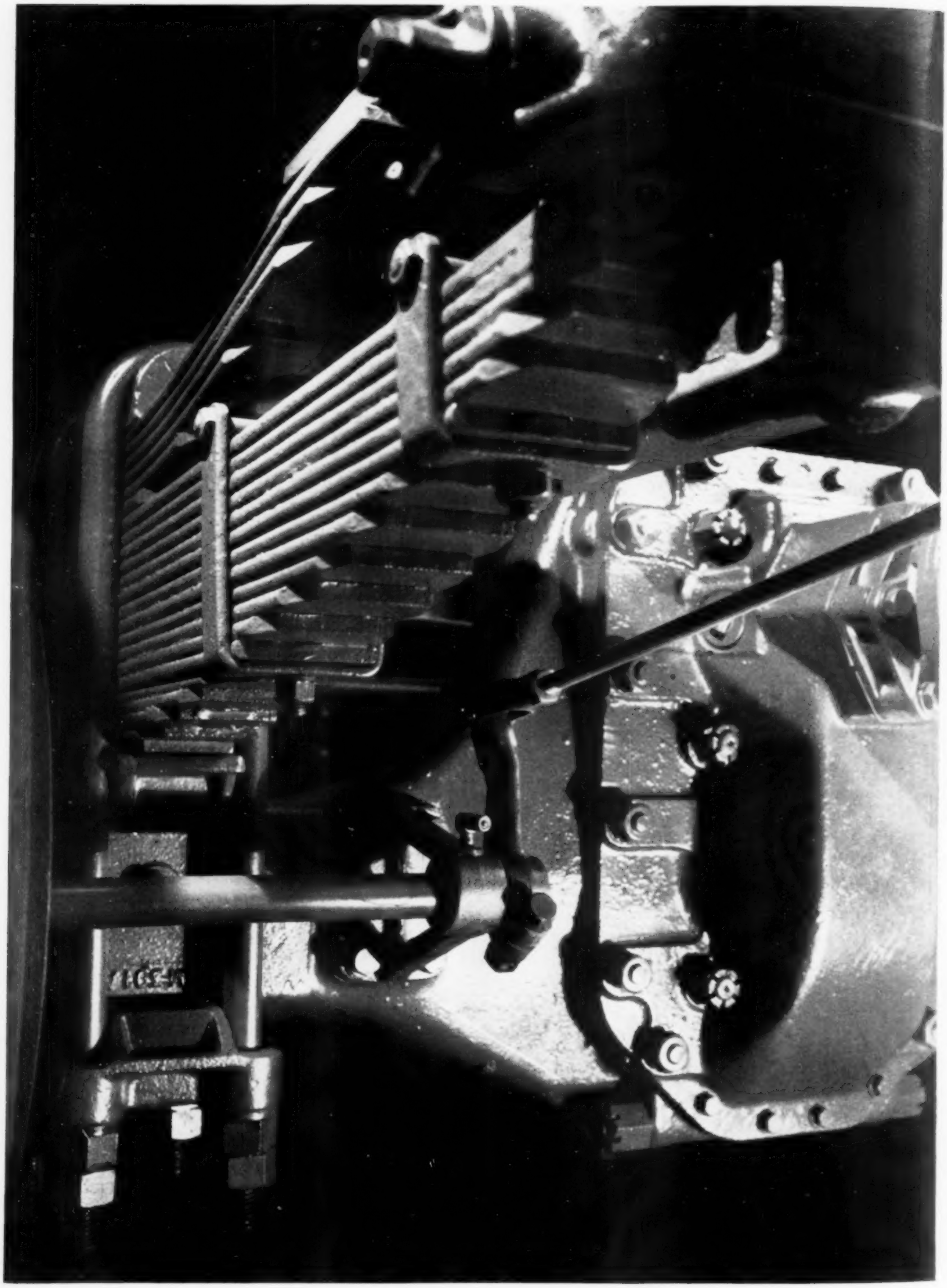
On page 19 FRED W. CEDERLEAF and W. E. SANDERS describe their investigation on the effect of density in forgings. Mr. Cederleaf, works manager of Muncie Products Division, General Motors Corp., was born in Sweden but came to this country at the age of three. His industrial experience has been unusually broad. Mr. Sanders is plant and metallurgical engineer for the same organization. He joined Muncie Products Division in 1919 as electrical engineer and was successively appointed chief electrician, plant engineer, and finally his present position.

Powdered metals, described on page 32 by CHARLES HARDY, have interested Mr. Hardy for some time. Mr. Hardy was born in Schleswig-Holstein and studied in Germany, London, and Columbia University, New York. An article on calcium from his pen appeared in the April issue of this magazine.

J. B. NEALEY discusses aluminum forging on page 43. Articles by Mr. Nealey have appeared in American technical publications for some time, as for a number of years he has described plants and processes as part of his work with the American Gas Association.

A director of the Society, BEN F. SHEPHERD, chief metallurgist of the Ingersoll-Rand Co., has contributed to the correspondence columns this month. Mr. Shepherd has been with his company since 1911 and has been active in the A.S.S.T. since its organization.

Metallurgical developments in France are described every month by ALBERT M. PORTEVIN, distinguished French engineer and metallurgist, who has published about 250 articles on metallurgy during his career. His work as teacher of metallurgical subjects and as consulting engineer to many prominent European firms has made him well known at home and abroad.



Strength, endurance, machinability, demanded of modern castings and forgings

Photo by R. T. Dooner for Autocar

Dense gear forgings are machinable and durable

By Fred W. Cederleaf
and W. E. Sanders

Mr. Cederleaf is works manager and Mr. Sanders is plant and metallurgical engineer of Muncie Products Division of General Motors Corp. This is a shortened version of a paper read before the inaugural meeting of Muncie Chapter, A. S. S. T., and at the June meeting of the Machine Shop Practice Division, A. S. M. E.

IN ANY PLANT manufacturing duplicate parts, the few forgings or castings that are below the average determine surface speeds and tool feeds. The minority, not the majority or the average, rules.

The reason for this is obvious. Setup time is expensive; changing tools costs money. The more pieces per setup, the less cost per piece. These few culprits, below the average, can wreck the setup on every machine in the line and at the same time burn the edge of the cutting tools.

It would be better to set feeds and speeds for parts having the least degree of machinability. Due to the demand that the shop reduce labor costs, we keep reducing the standard time and increasing the output per machine and depend on the receiving inspection department and the metallurgical laboratory to keep forgings and castings that are not up to the standard out of the line. When "somebody slips" and below-standard parts are accepted the manufacturing departments would fight the excessive cost, the metallurgical department would check and analyze, the purchasing department would call in the sources of supply and finally things would again resume their normal pace.

This procedure has been going on ever since we can remember, but the variation in machinability is still with us; also we succumb to the temptation to set feeds and speeds to the maximum rather than to the minimum. It is obvious that uniform machinability is of vital importance.

Machinability of gear forgings is of even more importance. The extra pounding or pressure exerted by a hob in its effort to cut gear teeth in below-par forgings, sets up a strain on the tooth profile. These strains are released when the gear is hardened, the steel changes shape and produces an involute that is so far off that absolutely unacceptable noise is produced in an automobile transmission.

The above is a description of the occurrences that started this research, about two years ago. The shop encountered difficulty in machining gear forgings, yet the metallurgist reported nothing wrong with the steel, analysis up to specification, hardness O.K., and grain structure correct.

To check against the shop report, three truck loads of forgings were delivered to a lathe hand in the tool room. He picked out the ones that machined O.K. without any difficulty whatever. The shop then finished approximately 40 gears per hob-grind on the forgings the lathe hand had set aside as good and 2 to 5 gears per hob-grind on those he had picked as being difficult to machine.

Samples were then sent to several other metallurgical laboratories. It was very definitely noticed that the complete section from the gear blank that machined well could be cut with one hack saw blade, while three hack saw blades were necessary for the others. In spite of this, the reports all agreed that any observed difference in Brinell hardness would not account for the difference in machinability, and that the microstructure of these specimens showed lamellar pearlite and free ferrite, an "annealed structure which is generally accepted to be best for machining."

Various suggestions were made as to how to remedy the trouble. One recommended keeping forgings from each heat separate through the shop and varying the annealing treatment and cutting practice. Another was to revamp the annealing cycle, and give a 1650° F. soak at the first. The third believed that the chromium content of these 5150 steels should preferably be in the neighborhood of 0.90%, rather than on the high side of the 0.80 to 1.10% range.

One would therefore conclude that the trouble lay in our inability to select the proper annealing cycle to suit the different heats of steel we could expect to receive under the specifications in force. This, of course, was confirmed by the mill representative, who stated that if we would leave the annealing cycle alone after he set it, we would not run into this trouble. This we were unwilling to do, for this cycle had been set by him some months previously and had worked reasonably well in the interim. Besides, we didn't know which way to change it if we would.

In our search for a quick machinability test on annealed forgings, we found that two principles had been worked on; one used a cutting tool until it failed to machine, and the other measured the pressure between work and tool.

Measuring the Machinability

However, neither method had been developed for shop use, so we tried another that appeared to be simple and positive: A standard Brown & Sharpe fly cutter arbor was used in a horizontal milling machine. Into this arbor was fastened a fly cutter having one cutting edge the full width of the tool; the latter measured ¾ in. square by 3 in. long. It was ground to a standard clearance angle but without rake, and measured from cutting edge to back of tool. A forging to be tested was clamped in the milling machine vise. A predetermined feed, speed, and depth of cut was used, the tool traversing the total length of the 8-in. specimen. This tool was then removed, the cutting profile enlarged optically, the amount of wear on the cutting edge computed and checked against values found from similar specimens of known machinability. In order to prevent breaking down the corners of the tool (which would happen if we would cut a groove through the forging) the specimen was machined in such a way as to present to the cutting edge of the tool a surface which was less in width than the tool.

At the outset of this particular investigation, and before the above-mentioned test was made, men were put into different departments to count the number of pieces per grind and note the finish. While this was going on, a group of 175 partly machined cluster gear forgings (which were under in length) were returned to the forge shop, reheated to 1800° F. more or less, restruck by a board hammer and re-annealed. It was noticed that these were improved in machinability by approximately 30%.

This suggested two causes, (*a*) that the improvement was due to the added heat treatments, or (*b*) that the gear, while expanded by heat, was struck and the metal compressed.

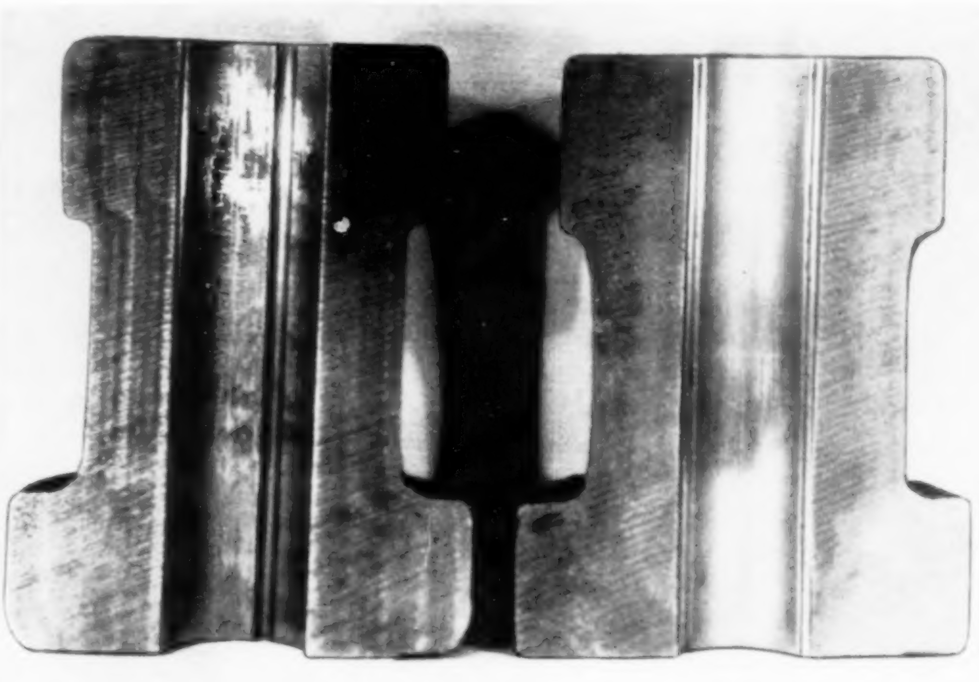
At the same time we were drilling and broaching some 3.5% nickel gears. Some showed a very smooth finish in the hole, broaching with considerably more ease than some others in the same lot. Some would tear badly in the drilling. The hydraulic broach would pull very unevenly, showing that greater energy was required to pull the broach through; the hole would be torn and very rough, as shown in the left hand figure, opposite.

One important difference may be noted. Some of these forgings had round corners while others had square corners. This suggested a difference in the way the die was filled at the time the piece had been forged. Pursuing this idea we selected many round-cornered, or unfilled, pieces; they always produced a torn condition in the finished hole, but when machining the square-cornered, or filled, pieces we obtained a very smooth surface in the hole.

These two findings pointed to the necessity of studying forging practice if we were to get to the bottom of the problem, and gave us something definite to work on. At the same time we purities, may etch in an entirely different manner after forging.

We believe that these "pock marks" developed by deep etching represent voids or cavities in the metal. On a milled surface, a thin film of metal covers these minute cavities; the acid attacks this thin film as well as the less dense metal in the cavity, increasing its size greatly.

The location, nature, and extent of these voids or cavities, as brought out by the etch test, determines the degree of density in any forging. Our theory is, substantially, that in forging it is possible to produce internal slipping or tearing



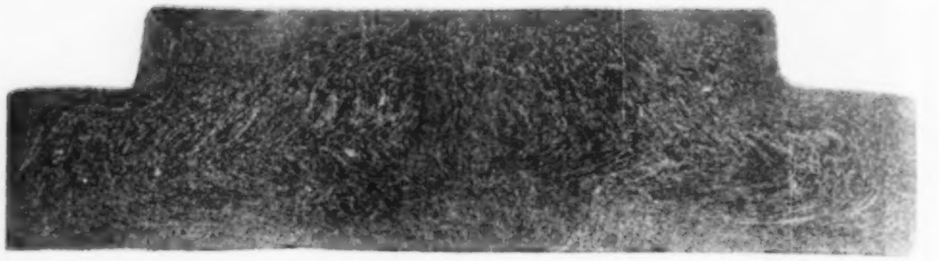
Drilled and Broached Holes in Gear Forgings. Pieces from same lot show wide difference in condition of surface when machined under equivalent conditions

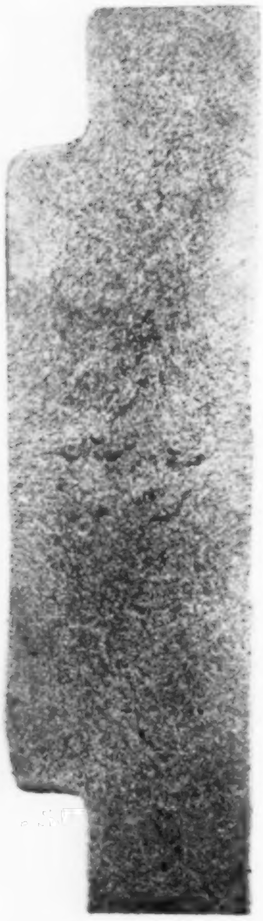
were busy in the laboratory, studying the structure of the gears, and were struck with the differences in the etched cross sections, not only in pieces from different heats (S.A.E. steels 2320, 4615, 5140, 1315, 3140, 3240, 2515 and 2520 were studied in this research) but in forgings from the same heat.

Deep etched specimens have been studied by many. The appearance is usually thought to be associated with the quality of the steel, the etching pattern being determined by the amount and nature of non-metallic substances present. With this the authors cannot quite agree. Two steels, of the same analysis and having approximately the same amount of non-metallic im- of the fibers in the steel, and the largest percentages of openness or coarseness shown by etching are due to torn fibers.

Having observed a large number of forgings in which the porosity was almost negligible, even after long etching, and others wherein it was quite pronounced and quickly developed, the authors were inclined to associate these conditions with the other variables in machinability discovered in the machine shop.

After an investigation of forge shop operations we found we must maintain a higher temperature, namely 2150° F. for S.A.E. 5140, and this must not vary more than 100° F.; the dies must be properly designed to avoid a flash





Metal in Upset Discs, Reheated and Hammered, Is Condensed by Additional Work. Top disc has two reheatings and 30 blows; middle 3 and 45; lower 4 and 60 blows by a board hammer. The machinability increases with the density

which takes the brunt of the blows and minimizes the compression on the metal in subsequent operations. In upsetting machines the flash should preferably be longitudinal with the heading tool.

After correcting dies and forging temperatures, machinability markedly improved. The next thing was to determine whether anything further could be accomplished by compression of the metal, because as far as could be determined, the only effect of proper heating was a satisfactory flow of the metal to fill the die.

Some pieces were therefore upset, reheated and struck 15 blows by a board hammer. The flash was ground off several of these pieces; they were reheated and again put under the hammer and the same operations repeated a third and fourth time. It was found that repeated hammering or compressing of the metal correspondingly improved the machinability. The pieces which had been repeatedly heated and hammered, showed upon etching that the original cavities had not been entirely closed. There was evidence of adhesion at the cavity surfaces, but not cohesion. Representative macrographs are shown on this page.

Our next thought was to discover what characteristic of the steel prior to forging produces more ductile fibers, and thus promotes flow of the metal without tearing. What is the relative effect of coarse and fine grain?

A bar of 0.50% carbon, 1.0% chromium steel was selected. It had a medium fine structure in the rolled condition. Some forgings labeled *A* were made from one end of this bar; the balance was cut into suitable lengths and furnace cooled after soaking for one hour at 1650° F. Half of these were then upset into the same forging, and labeled *B*. The balance were reannealed at 1750° F. and upset (labeled *C*). Microscopic specimens showed the structure to be coarsened considerably after each anneal.

The three groups of the forgings were then cut and etched. There was a progressive decrease in the amount of torn fibers, and a like increase in the continuity of the flow lines from *A* to *B* to *C*. The increased density of forgings *B* and *C* made it necessary to etch them 10 min. longer to bring out the flow lines.

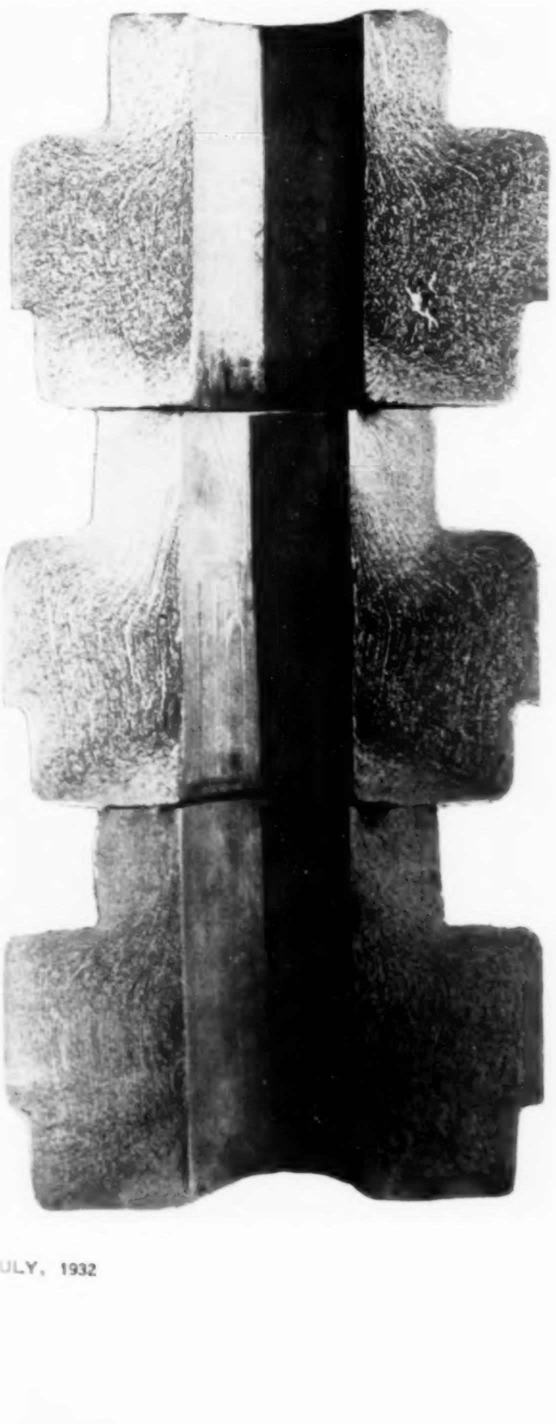
In view of these findings, it was thought advisable to investigate a variety of steels having different McQuaid-Ehn grain sizes. Arrangements were therefore made with the steel companies to furnish a few bars having grain size ratings from 1 (coarse) to 9 (very fine). These bars were heated to 2100° F. and different sized upsets were made on the end of the bar in ratios from 1½ to 1 up to 7 to 1 in 10 steps. It was noted that the coarse grained steels were more ductile and did not tear in the upsetting.

while more porosity developed in the finer grained steel.

It was also discovered that the coarse grain not only affords greater density when upset but also permits piercing of smaller holes of greater depths or lengths.

A larger quantity of steel was then made of the coarse grain variety, graded at 4 to 6, and forgings were made into test gears. It was noticed that the inner structure of the

Top Forging A is From a No. 7 Grain Steel; Fibers are Sheared Diagonally Upward From Lower Corner. Middle and bottom forgings B and C were made after grain size was coarsened (by annealing bar end) to 6 and 5 respectively. They have progressively less rupture, flow lines are better defined, and metal at hub has greater density. An extra ten minutes was required in the etch



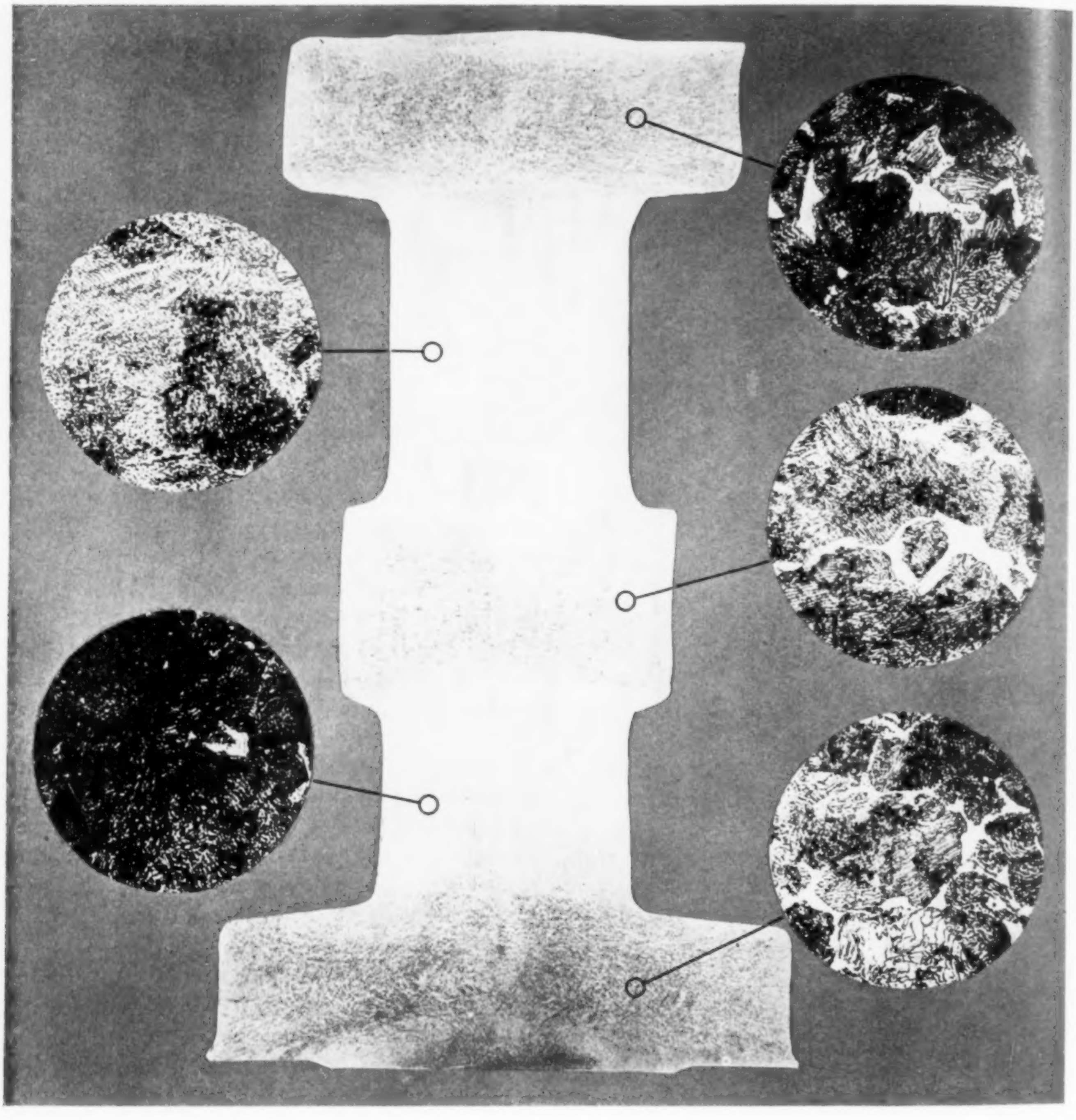
forgings had been materially improved but there was still some evidence of torn fibers. We then began to consider the ingot size, recognizing the fact that a smaller ingot, with less fibers over a given area to be controlled or made ductile, might lead to further improvement. To substantiate this, arrangements were made to have a test run on steel of coarse grain, namely 4 to 6, cast big end up in different sized ingots. The ingot molds were all fluted, of the Gathmann type, with hot tops.

One heat of steel was cast into 12, 17, 19, 20 and 21-in. ingots and another heat in 23, 26 and 28-in. ingots. Bars, rolled from each of these ingots, were upset and tested as described above. The best results were obtained with a 4 grain size from a 19-in. ingot. Further to confirm the results, a large quantity of gear sets was forged from the last mentioned steel for annealing, machining, hardening and dynamometer tests for durability.

Being fully aware of the more or less prevalent ideas that fine grained steels are practically the same as coarse grained steels in yield point, tensile strength and elongation, but that fine grained steels are tougher, have higher impact values, less distortion in heat treatment, and wider hardening ranges, we naturally proceeded with this research on grain of steels very cautiously. Pieces were machined, and, teeth being cut, they were put on the "red line test" before and after hardening to determine change in shape. Repeated tests showed distortion to be uniform and it could be allowed for in the cutting.

To quote C. H. Stanard, our gear supervisor: "Since we have been getting forgings with greater density we have maintained an accuracy of contour on hobbing machines within 0.00025 in. When they come out of the fire, we can expect about 0.0004 to 0.0005 change in contour and no apparent change in spacing. Gears going to the fire with concentricity less than 0.001 return with 0.0015.

"A great deal of deformation is caused by cold working of the metal when the hob loses its keen, sharp edge. In going through the fire the strain is relieved and the portion cold-worked will rise above the other portion of the profile. As the portion around the point of the hob tooth removes the most stock, it is important that the metal being cut be dense and not cause undue wear at this point, as this portion forms the flanks of the teeth, their most sensitive area, and the most difficult to correct by burnishing or lapping."



Improper Forging Causes Poor Microstructure after Anneal. Undisturbed bar has uniform pearlite; upset portions have excess ferrite and are hard to machine

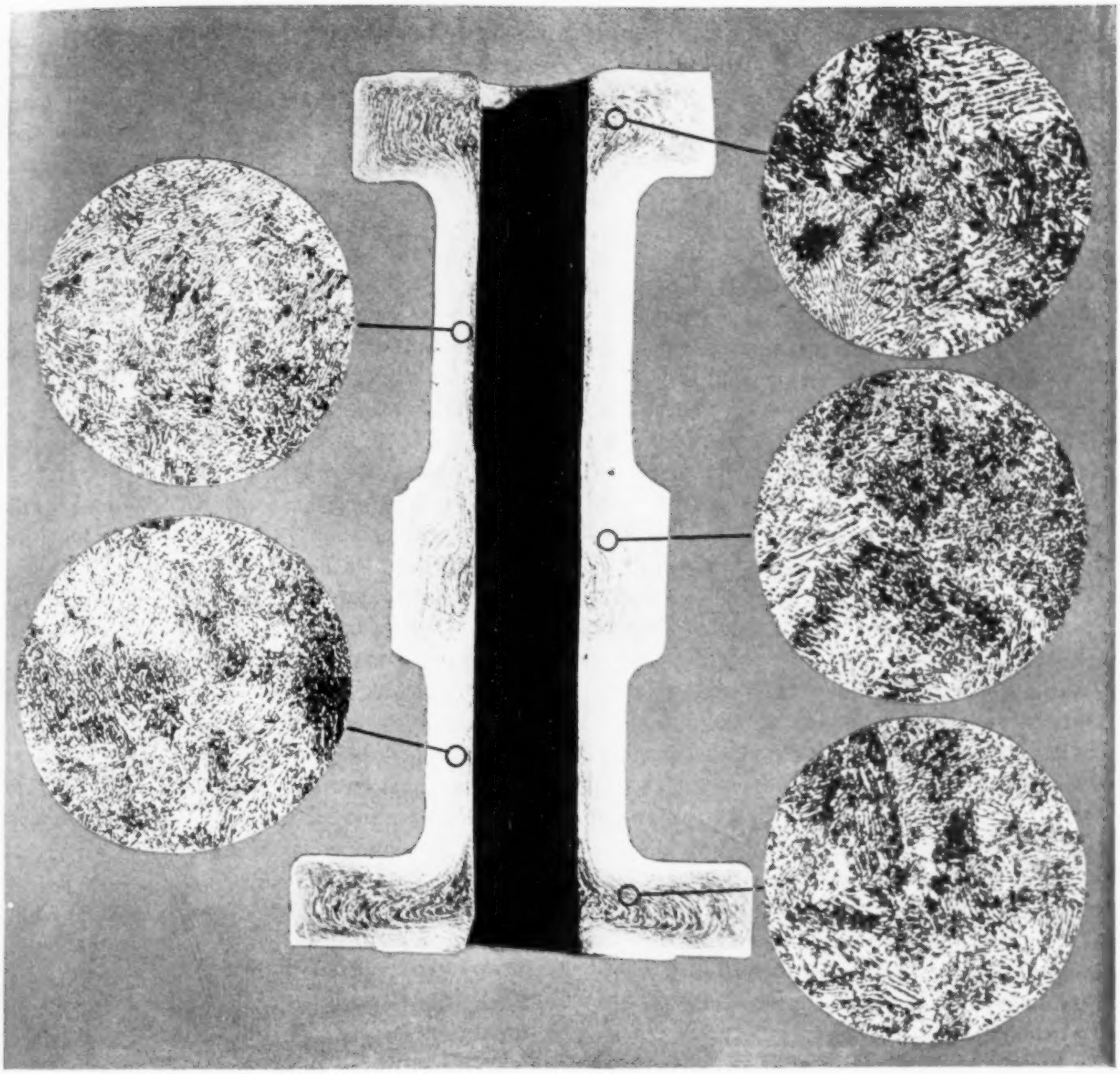
Some dynamometer tests were run on four assembled transmissions mounted on fan dynamometers; 40-hp. loads were applied with the transmissions in second gear and operated for 15-min. intervals. Between intervals they were allowed to cool while the wearing surfaces of the gears were examined. Examination of these gears, after they finally broke down, disclosed that the surface pits on the gears made from filled forgings were considerably smaller than those on the gears from unfilled forgings.

Average temperature rise in a 15-min. working interval for each transmission was:

Unfilled, No. 1	146° F.
Unfilled, No. 2	159° F.
Filled, No. 1	116° F.
Filled, No. 2	126° F.

Transmissions made from filled forgings operated at higher efficiencies because of less frictional losses.

All four transmissions were operated as outlined above until a breakdown prevented further testing. One or more teeth broke out of



Properly Forged and Compressed Steel of Coarse Grain Size Anneals Uniformly in All Sections. No fibers are torn, even by the deep piercing operation and all machining operations are greatly improved

the second speed countershaft gear in each one. Total number of hours before breakdown was:

Unfilled, No. 1	80 hr.
Unfilled, No. 2	70 hr.
Filled, No. 1	126 hr.
Filled, No. 2	128 hr.

These hours are equivalent to like numbers in thousands of miles of service. It may therefore be safely concluded that gears from filled forgings excelled the others in hours operated before granulation and pitting, in cooler operation, higher efficiency, and longer total life.

Another of the dynamometer tests, in which the horsepower was built up to approximately 300, tore out teeth on the sliding gear in a suggestive manner, and we thereupon investigated the impact strength of the gear teeth.

In this test the gear is clamped in a fixture, an anvil is placed on a tooth of the gear and a 10-lb. hammer is tripped from increasing heights until the tooth is broken out. The apparatus is quite similar to the one described by Fred C. Raab in "Brown-Lipe-Chapin's Gear Testing Fixtures," METAL PROGRESS, March, 1931.

The tooth nearest the torn section broke out with a 20-in. drop of the hammer, while the tooth on the opposite side broke out with a 48-in. drop. Investigation of the gear blanks disclosed that the forgings showed less compres-

sion or density on one side than on the opposite side. The cone, formed in the first upsetting operation, was eccentric to the bar, and one side of the gear blank failed to fill the die because of this unequal distribution of metal. All of the evidence supports the conclusion that highly compressed metal makes better gears.

We will now endeavor to show the marked superiority of the improved forgings over the old type in their response to standardized annealing treatments. A hump furnace was filled with forgings of a given type, heated to 1600° F. and allowed to cool in the furnace. Three such loads of unfilled or porous forgings produced a cooling curve with a very short hump at Ar_3, while the humps for the furnace-loads of filled forgings (a more dense material) are considerably longer and approximately 40° higher. This shows that the decomposition of the austenite into pearlite takes place at a higher temperature and takes a longer time.

In an additional study of the reason for the material being irresponsive to the annealing treatment, a cluster gear forging taken from the center of the discharging load from the annealing furnace was sawed through the center and etched. The center boss which forms the idler gear, shows the fibers to be torn and open, less compressed than the two upsets on either end.

The fibers of the steel upsets on both the ends have been torn probably as much as the fibers in the center, but the greater compression has effected some adhesion.

Photomicrographs were then taken (page 20) representing the various sections of this cluster gear, and show clearly the non-uniform response of the less dense or porous sections to the annealing treatment. The upsets show islands of massive ferrite, a very poor structure for machinability. The sections of the bar which were undisturbed in forging exhibit a fairly uniform structure of lamellar pearlite with very small islands of free ferrite, a more suitable structure for machinability. These structures seem to prove definitely that the sections of the cluster which were disturbed in forging do not readily respond to the anneal.

For comparative purposes we then made a similar analysis of one of the improved cluster gear forgings made from steel having a No. 4 grain size rating. Micrographs were taken in comparable positions and show structures all quite alike, indicating a very uniform response of the entire forging to the annealing treatment. This uniformity is no doubt the result of the more dense structure produced by the present upsetting methods applied to coarse grain steel.

In this research we have proven, we think beyond a doubt, that these cavities or voids which affect machinability are due to a spongy metal at the cutting edge of the tool. The tool has double duty to perform, (*a*) closing the cavities with adjacent metal so that it has proper backing, and (*b*) cutting. After correcting the forging practice we found an improvement in machinability of 50% to 400%, depending on the operation. Speeds and feeds had been increased 10% to 60%, and tool life was increased in like proportions.

We have selected as an example the cutting of gear teeth on the gear hobbing machines, showing the number of pieces per shift of hob, the hob having four shifts per grind. The following table compares machining results today with the results obtained a year ago. At that time the steel was purchased without grain size specification and no precautions were taken in forging to develop increased density.

	Pieces per Shift of Hob	
Part Name	December 1931	December 1930
M. D. Gear	35	27
Second Speed	35	24
Sleeve	14	8 to 10
Low Slider	70	60
Cluster (17 tooth)	35	20
Cluster (20 tooth)	30	20

All are finished in one cut with 0.060 feed per revolution of blank.

In addition to this improvement in machinability we might add that the overall tool cost has been reduced from 84¢ to 44¢ per unit.

In summary, we have found that we can produce a denser forging in all our gear steels by using coarse grained steel, accurate temperature control and correctly designed dies. Such dense forgings anneal more uniformly and may be machined at greater feeds and speeds, even while reducing the tool costs nearly half. These machined gears respond uniformly to hardening, the change in volume being predictable. Dynamometer tests indicate an increased life of 50%, marked decrease in pitting and granulations, and a stronger, smoother and quieter gear.

By Ernest E. Thum
Editor Metal Progress

Manufacture of high strength wire

CIRCUMSTANCES surrounding the breakage of wire at low load in the main cables of two important suspension bridges were described in the last issue of METAL PROGRESS and it was concluded that the trouble was not due to abuse during erection. No breakages occurred during spinning except those that were considered ordinary construction accidents, such as from a kinked wire. The trouble developed after the bridge was finished except for the roadway slab.

Since steel wire has been used with entire satisfaction in many another suspension bridge, the next thing to do is to investigate the defective wire. Was it made of unsuitable steel? Was it abused during manufacture?

Much difficulty is associated with such an inquiry, for the American wire industry follows traditional methods in its operations. Precise information about the effect of variations in dozens of the manufacturing details (such as speed of drawings) is either entirely lacking or known to the few.

Under these circumstances the best approach will perhaps be to describe briefly the method of manufacture of the cold drawn steel wire used so successfully for all wire suspension bridges, and as manufactured by John A. Roebling's Sons Co., American Cable Co., and American Steel & Wire Co., and then compare it with the methods used for making the heat treated wire first erected in the Mt. Hope and Ambassador bridges.

Cold drawn bridge wire for the George Washington bridge across the Hudson River at New York City, made by the Roebling organization, and the cold drawn wire manufactured by the American Cable Co. (to replace the heat treated wire first erected) and which is now in the Mt. Hope and Ambassador bridges conformed to the following specifications: Carbon 0.85% max., sulphur 0.04% max., and phosphorus 0.04% max.

Ladle analysis of the last mentioned material showed carbon 0.80%, sulphur 0.039%, phosphorus 0.038%, manganese 0.62%, and silicon 0.20%.

Steel for the George Washington bridge was made in acid open-hearth furnaces from clean plate scrap and high-manganese pig iron.

The metal was teemed into big-end-up ingots with refractory sink heads, cooled, reheated slowly, and rolled by small reductions into a 2x2-in. billet. Prior to the last pass it was shaved on all sides 0.02 in. Any heat which showed pipe or any axial defects or surface imperfections on the billets was scrapped. Reheated billets were then rolled to about 3/8-in. rods in a continuous mill.

The unsatisfactory wire for Mt. Hope Bay and Detroit River bridges was rolled in the wire

drawer's own rod mill to 0.225-in. rod from purchased 2-in. billets made of killed basic open-hearth steel in accordance with "special discard alloy practice." Analysis of the finished wire conformed approximately to the following: Carbon 0.80%, manganese 0.40%, silicon 0.20%, sulphur and phosphorus both less than 0.02%. One end of each rod was clipped, polished, and pickled in acid. Acceptance by the wire mill depended upon this 100% deep etch test for soundness.

Is this raw material unsuitable?

Whether acid open-hearth steel is better than basic is a controversial point, very difficult to decide, since the evidence is so likely to be warped by personal prejudice or business considerations.

Conversations with steel makers experienced in the art of making fine steels by both processes has brought out the opinion that acid steel is a little cleaner, is a little more consistent in final physical tests, and has a higher elastic limit for the same carbon content. Wire drawers generally prefer acid steel for their best product, believing that it can successfully be put through a series of reductions which would cause sporadic breakage at the die in an equivalent basic steel.

This matter is one of the intangibles pervading wire drawing practice. It certainly does not mean that very fine grades of wire for springs, rope, and other uses cannot be made by the basic process. Quite the contrary; great tonnages of it *are* so used with entire satisfaction.

Experience, therefore, indicates that there is no reason why the choice of basic open-hearth steel instead of acid for the first Ambassador and Mt. Hope bridges should be regarded as the determining factor in the failure. The fact that our common grades of merchant steel are made in basic furnaces, while acid furnaces are usually reserved for fine steels, should be ascribed to the nature of our available ores and scrap rather than an indication of the inherent capabilities of the two processes.

Another point may be made — that the manufacture of the Mt. Hope and Ambassador wire had no control over the making of the steel and its rolling into billets. This might be a controlling factor in some specialties, but probably is not in the manufacture of wire. Many wire mills have no rolling mill and consequently must purchase all their rod and strip in the open market. About a million tons of it go from steel mills to independent finishers in a normal year. Consequently, the technique of manufacture of wire-making steel is well understood by several producers, and methods of inspection are well known. Incidentally, the sulphur and phosphorus analysis of the metal is a strong indication of a quality product.

It is fair to conclude that the Mt. Hope and Ambassador wire failure was not due to the use of basic steel rather than acid, nor due to divided responsibility.

But the manufacturing procedure for the first Ambassador and Mt. Hope bridges is quite different from that for successful hard drawn bridge wire. They are in truth two entirely different end products, although starting from substantially the same original material. One was hard drawn from a patented rod. The other was lightly drawn from the hot rolled rod as delivered and then heat treated.

Since patenting is a most essential operation for high strength cold drawn wire, and is a unique heat treatment, it may be described at some length.

The microstructure of any hot rolled rod (the raw material for wire) will reflect the chemical segregation inherent in the ingot, and a longitudinal section would give plenty of evidence of a banded structure.

Furthermore, the constitution (and hardness) of the best-rolled rod varies slightly throughout the coil. To minimize these variations, a modern continuous rod mill is coupled so close and runs at such a speed that the front end is finished and being reeled before the rear end of the 30-ft. billet has emerged from the reheating furnace. Theoretically, then, the temperature of the rod as it emerges from the finishing pass should be uniform, end to end, and well above the critical. Coils are cooled slowly and uniformly in a covered conveyor. Nevertheless, owing to the fact that the outer layers of a coil cool more quickly than the inner ones, there will be a corresponding and somewhat haphazard variation in microstructure along the rod's length.

Patenting is designed to remove these dif-

ferences caused by ingot structure and non-uniform cooling, and to replace them with a uniform structure of sorbite known to have maximum ability to withstand the subsequent stresses of wire drawing.

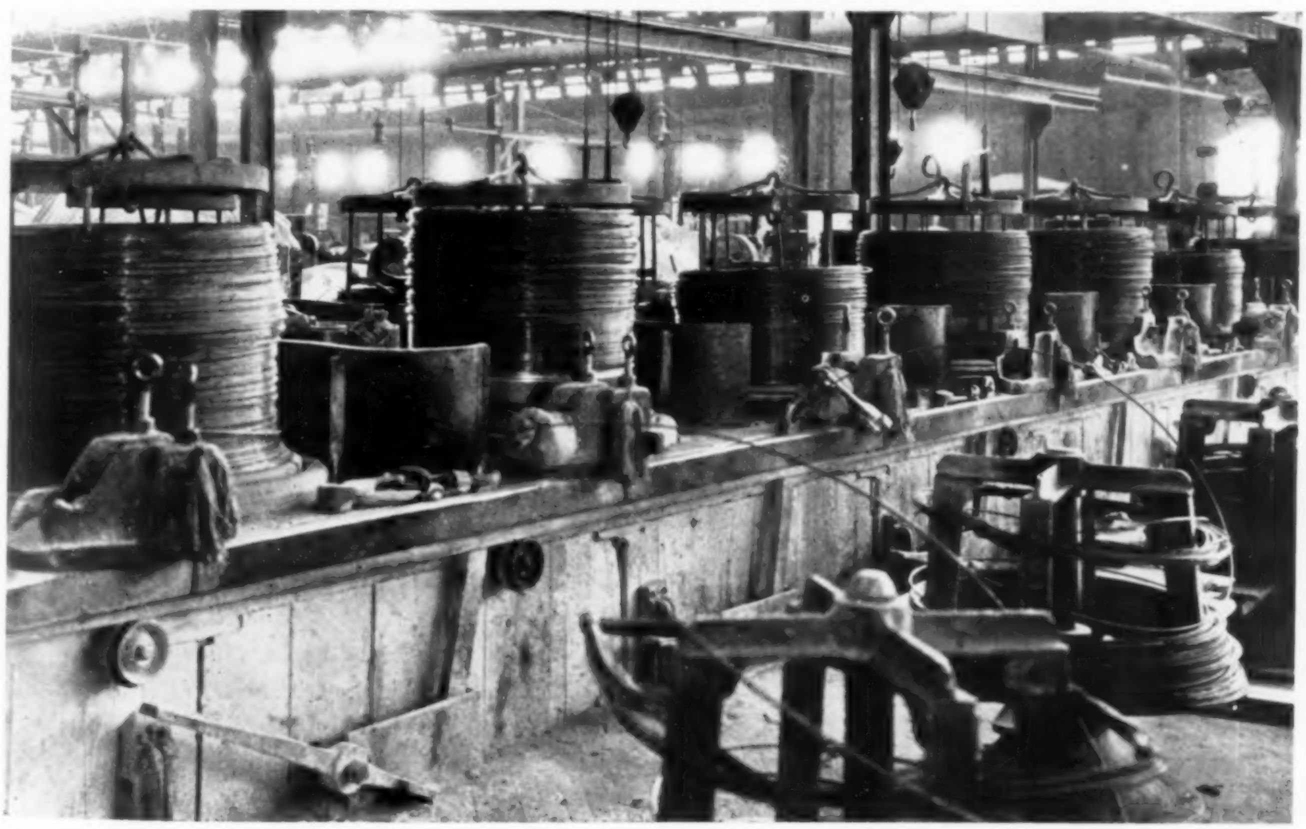
Patenting of ⅜-in. rods is done in a muffle furnace from 50 to 100 ft. long, through which are drawn a dozen or more rods, side by side, at a very deliberate pace. Within the muffle is maintained a correct gas atmosphere to prevent surface decarburization. Temperature of the rod reaches the critical fairly close to the entering end, and increases gradually toward the other. This method of heating and soaking produces comparatively large equi-axed austenitic grains, with a high degree of uniformity as to grain size and distribution of atoms in solid solution in the iron.

Emerging from the furnace some 300° F. above the critical, the rod passes directly into a lead bath (temperature is varied between 850 and 950° F. for different heats of steel and as determined by tests on sample rods run through in advance). The entire microstructure should then be sorbite. Few traces of crystal boundaries can be seen under the microscope, but when the rod is eventually hard drawn for correct strength, the wire has a quasi-fibrous microstructure.

The rod in the patented condition is very stiff and hard. The ultimate strength of the green rod (about 150,000 lb. per sq.in.) has been increased to the order of 170,000 lb. per sq.in., and the elongation is about 8% in 10 in. To convert such a patented rod into bridge wire, it is cleaned and drawn through four dies of successively smaller diameters, one die at a time, emerging finally as No. 6 wire, 0.192 in. diameter. This "bright wire" has its strength and toughness induced by cold work; its ultimate strength is about 240,000 lb. per sq.in. and the elongation is 2 or 3% in 10 in.

It is worthy of repetition that correct patenting is regarded by wire makers as absolutely essential for cold drawn wire of high strength. Hasty work, incorrect temperatures, or non-uniform conditions will cause a great variety of subsequent troubles, such as breakage in the final drafts, or a deficiency in toughness as measured by the ability to stand the required number of twists. (This test is variously made. Sometimes a length of wire is bent into a hair-

Drawing of Bridge Wire by 30-Inch Blocks. Courtesy Port of New York Authority



pin, the loose ends fixed in a vise, the loop put over a hook, and turned so the loop twists itself together like a tourniquet. Bigger wire may merely be gripped in head and tail stock of a lathe or torsion testing machine and twisted until it fails.)

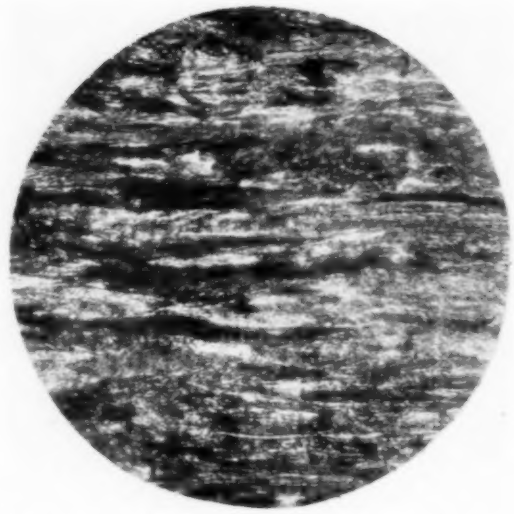
Heat treated wire first erected in the two bridges was made in accordance with the usual method for making oil tempered spring wire (somewhat revised). This method differs widely from the steps followed in the manufacture of cold drawn wire. The hot rolled rod was not patented, but cleaned and given one, or at most two, drafts to its finished diameter, 0.192 in. This amount of work presumably penetrated the metal to the center and thus made it more amenable to the heat treatment that immediately followed.

High strength was to be induced not by cold work but by quenching in oil and tempering. Heat treating for strength and subsequent cleaning and galvanizing was a continuous process; the wire was drawn through a succession of tanks and reeled on 5-ft. blocks at the far end, completely processed and ready for shipment. Nearly all the wire was inspected magnetically to guard against irregularities in heat treatment.

First in this line-up were four lead tanks in series, each about 12 ft. long, set close together end to end, wherein the cold wire was given two definite heat treatments. In the first it was preheated somewhat below and in the second brought about 200° F. above the critical temperature. This recrystallized the metal into an austenitic structure. It immediately entered the third lead pot, about 300° cooler, wherein it was cooled slightly below the critical.

So far the treatment might be characterized as a patenting operation. Then in the fourth lead bath at about the same heat as the second it is brought back to the quenching temperature. Wires were led through some fused salt directly down into an oil quenching tank, maintained at 275° F. Submerged in the oil were 12-ft. sheaves, side by side, around which the now hardened wires passed; then up and out in a sloping direction.

Tempering was done by submerging the traveling wires in a long lead pot at about 800° F., somewhat cooler than the galvanizing bath to be reached later, but this temperature was



Longitudinal Section of Cold Drawn Bridge Wire. Courtesy of the American Cable Co.

varied somewhat, heat to heat, depending upon minor variations in composition and processing of the wire. The rod then passed on to hot, dilute sulphuric or hydrochloric acid for cleaning, then wash water, then a light flux, then into molten zinc at about 850° F. (The latter routine is essentially the same galvanizing operation to which cold drawn bridge wire is subjected.) After passing up and out of the zinc pot and partially air cooling, it was further cooled in a water bath and passed through a solenoid for magnetic test.

This entire heat treating unit was controlled from one pulpit, where were located the pyrometer dials and all gas valves. All responsibility for continuous control was therefore upon one man. There is no doubt but that the heat treatment was well done, and the resultant product was uniform (in the commercial sense).

A number of these operations on the first Mt. Hope and Ambassador wire are unconventional, even for making heat treated spring wire. For instance, few manufacturers would dispense with the preliminary patenting heat treatment, (certainly not when drawing to small sizes) but probably none of them could cite quantitative data to support their views. They would be inclined to say, "You would get into trouble if you don't patent" — by that meaning that breakage at the die would be more severe, that a revised drawing schedule would be necessary, and that the twist test would give results below expectations. It should be remembered, however, that patenting is preliminary to severe

Longitudinal Section of the Heat Treated Bridge Wire. Courtesy American Cable Co.

cold drawing, and is the only heat treatment cold drawn bridge wire receives. The Mt. Hope wire was not cold drawn for strength, *that* was to be induced by standard good heat treating practice.

After diligent inquiry, the present writer believes that the wire industry has no convincing answers to such questions as these: "What is the minimum number of draws or the minimum reduction in cross-section necessary to give a wire rod so the wire will properly respond to heat treatment?" "Is rapid normalizing of No. 6 wire in lead baths sufficient to erase traces of ingot structure?" "What effect will traces of ingotism have upon wire?"

Since the wire industry places so much reliance on tradition, and has such a meager body of authoritative data, it behooves them and us to withhold criticism about the mechanical details of the Mt. Hope wire manufacture. It was made by men who were old hands at the game, and had only recently produced the cold drawn wire for the very large bridge across the Delaware River at Philadelphia. The most we can say is that it was unconventional and experimental. It was the result of independent thinking of men who were attempting to apply modern processes to an old operation. It was designed to produce material of high elastic limit, capable of being safely loaded at a higher unit stress than cold drawn wire. The responsible consulting engineers might be criticized for experimenting with a costly suspension bridge, but if the experiment had succeeded they would have been hailed as scientific trail blazers. Unfortunately, the experiment failed, and in our present state of ignorance we should curb the temptation to pin the blame on any single departure from the routine practice found in other wire making plants.

For these same reasons I believe one should discount suggestions that the heat treatment was done at incorrect temperatures. Wire, like other products, is susceptible to "blue brittleness," Stead's brittleness, to grain growth, overheating, and under-tempering. Also the chemical composition of the wire and its heat treatment must both be properly adjusted to the work it is to perform.

One acquainted with the personnel of the manufacturing staff and its research engineers will grant them the ability to understand these elementary principles and provide for them in the production routine. Troubles due to the above-mentioned irregularities and errors should at any rate quickly have manifested themselves in the ability of the wires to stand the routine tests constantly made on the material in process, and by the purchaser's inspectors.

"Non-uniform heat treatment" can be discarded in view of the centralized control of all temperatures, the magnetic testing of the wire, foot by foot (undoubtedly sensitive to variations in structure), and the acceptance tests on each coil. Finally, the Bureau of Standards reports, after much searching, that "laboratory tests did not reveal any characteristics to arouse suspicion, either in structure or properties."

It is beyond doubt that the practices used, unconventional though they were, manufactured wire that passed the routine and acceptance tests so successfully that it was accepted by at least six responsible bridge engineers (among the present leaders in the profession) as a superior product. It is also a fact that critics of the practice would rely upon these same routine tests — torsion and tension tests — to indicate any supposed damage done by overdrawing, underdrawing, overheating, underheating, or what not.

To return, then, to the question asked at the outset — "Was the wire abused during manufacture?" — the reply must be: "Not proven by its performance during manufacture or by the tests we use to determine quality in wire."

Manufacture and use of powdered metals

By Charles Hardy
New York City

POWDERED METAL — that is, metal subdivided to a very high degree of fineness — has been an article of commerce for a long time; one needs only to mention gilding and bronze powders. A recent development in this class of materials by the Aluminum Co. of America has been quite successful in expanding the market for aluminum paint and ink, wherein the "pigment" is powdered white metal. Much finely divided metal and sponge metal have also been absorbed by the chemical industry, either for reducing reagents or for catalyzers.

This article will indicate how an entirely new field has recently been opened for metal powders used as raw materials for synthetic alloys. To the uninitiated it might seem to be a waste of energy to powder pure metal, only to reconsolidate it into rods, bars, and tubes, but the method of manufacture is wasteful neither of energy or expense and the pressed and heat treated powders have useful and unique properties which justify the means of fabrication.

Before discussing this phase of the subject, brief mention of the methods for powdering metal should be made. Powders for paints, ink, and gilding are made by grinding. This class of material really should be called "flaked" metal, for the individual particles are microscopic leaves, and the covering power depends upon the way these leaves lay flat against the surface and overlap at their edges. Bronze particles, for instance, are on the order of 0.001 in. thick and from 5 to 25 times as wide and broad. Metal ingots for grinding into flakes should be quite ductile, so the fragments may be pounded out thin. Initial crushing is ordinarily done by the heavy impact of falling weights (as a stamp mill) and final grinding in a ball or rod mill — a rapidly rolling barrel full of tumbling steel or quartz balls or hard steel shafting. For pigments, particle shape is of more importance than uniform particle size, and consequently the grinding of each batch is done by program clocks. Various colors in the powders are attained either by alloying in the original ingot, or by heating at various temperatures in controlled atmospheres. Grinding and coloring operations must be done in small isolated units and in such a way as to avoid sparks, since some of the powders are highly combustible, and disastrous explosions have occurred.

Metal powders for the chemical industry are usually made by reducing the purified oxide in a correct atmosphere (ordinarily hydrogen).

One characteristic of this product, as shown by the micros on this page, is that the individual particles are rounded in shape — a matter of prime importance in the control of chemical reactivity, but a circumstance which militates against successful consolidation of the powder by pressure. Reduced oxides are also rather expensive and difficult, if not impossible, to reduce entirely, owing to the well-known difficulty of driving a reversible reaction to completion in one direction.

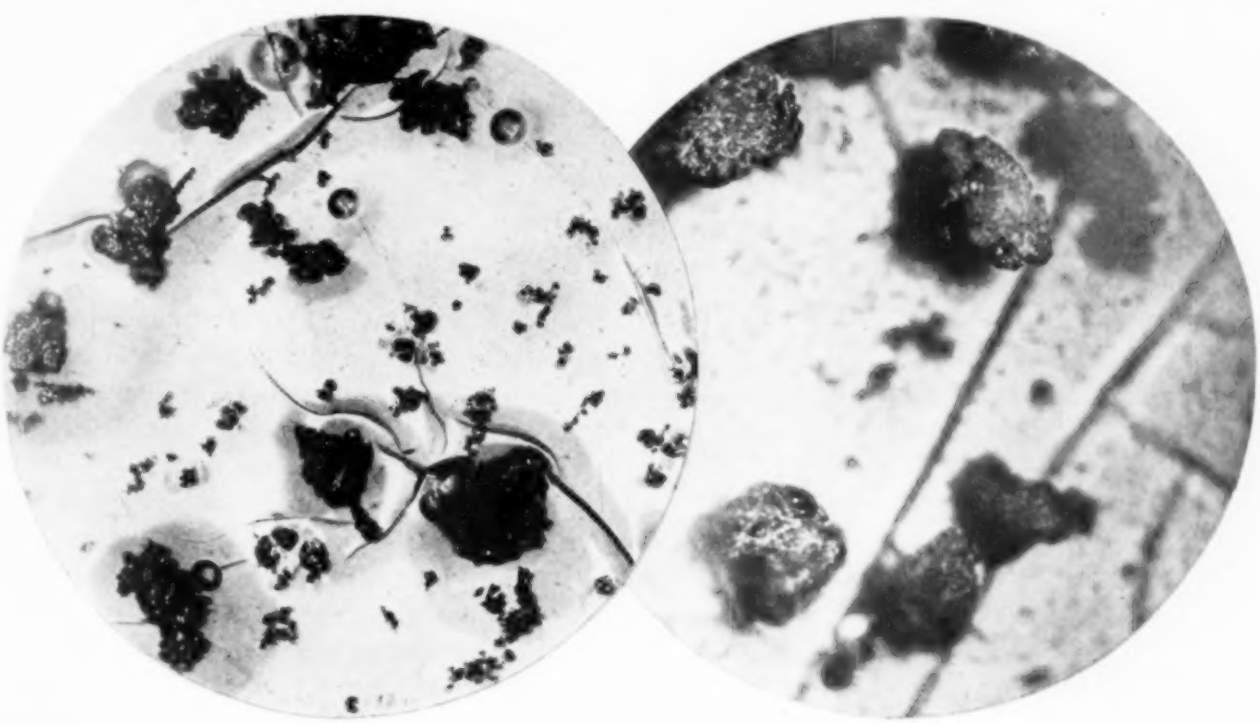
So-called "blue powder" is a type of material which has considerable use as a reagent. This is a by-product of zinc distillation; the zinc vapor which escapes from the condenser forms a metallic fog in a prolong. Each tiny droplet of metal has just enough oxide on its surface to prevent "wetting" of particles in mutual contact, so the contents of the prolong never accumulate into a liquid puddle. Zinc and other low-melting metals may also be shotted for chemical purposes by pouring a thin trickle of metal through a strong air blast.

In addition to pigments and chemical reagents another and most recent use for powdered metal is for reconsolidation into useful shapes. Briefly, the process consists of filling a proper mold with the powder, squeezing it so it coheres, and then heat treating the pellet so the particles weld together at contact points. Metal powder for this use should consist of particles with rough surfaces to interlock while the forming pressure is on, and should also be free of oxide which would prevent the actual intergrowth or welding of the metal crystals where they touch. Since the metal particles should be as pure as possible (so the properties of the fabricated shapes may be highly uniform), one naturally turns to the electrolytic process as the correct source.

Brittle metal, crushed mechanically, should present sharp angular corners and jagged surfaces. Furthermore, if the metal is deposited by current under such conditions that hydrogen is plated out simultaneously, the cathodes will be very brittle, and the hydrogen impurity can easily be removed by subsequent baking.

Brittle electroplates have been utilized as a source of powder, but are more expensive and less adaptable than the process of depositing pulverulent metal directly in the electrolytic tank. At the present time the following are being produced in this manner commercially: Chromium, iron, nickel, copper, silver, tin, zinc,

Particles of Copper, Magnified 200 Diameters. Rounded nodules were reduced from oxide; angular fragments were deposited from solution by electric current



molybdenum, and tungsten. Those skilled in the art of electroplating or electrolytic refining know that the temperature and concentration of the electrolyte, the current density and voltage, the nature and disposition of anodes and cathodes must all be kept under control and within proper limits in order to produce a dense deposit at a uniform rate. They will readily appreciate that a considerably different set of conditions, no less rigidly set and maintained, will operate at good current efficiency and bring down a spongy deposit which, when removed and washed, will reduce to an impalpable powder under the gentlest rubbing. In fact, many budding electrochemists will admit that it is far easier to get a spongy deposit than it is a sound one!

It would therefore be beyond the scope of this article to indicate many of the very large number of ways the job can be done for the metals listed. A number of patents cover the production of powdered metals. For instance, two methods are being used for copper on a considerable scale at this moment. One introduces a catalyst in the electrolyte and closely controls the amount of copper in suspension and the temperature of the electrolyte. Another deposits copper with very high current densities, as high as 350 amp. per sq.ft.

Type of Hydraulic Press Used by Carboloy Co., Inc., to Compress Mixtures of Tungsten Carbide and Metal Binder Into Accurate Shapes for Metal Cutters

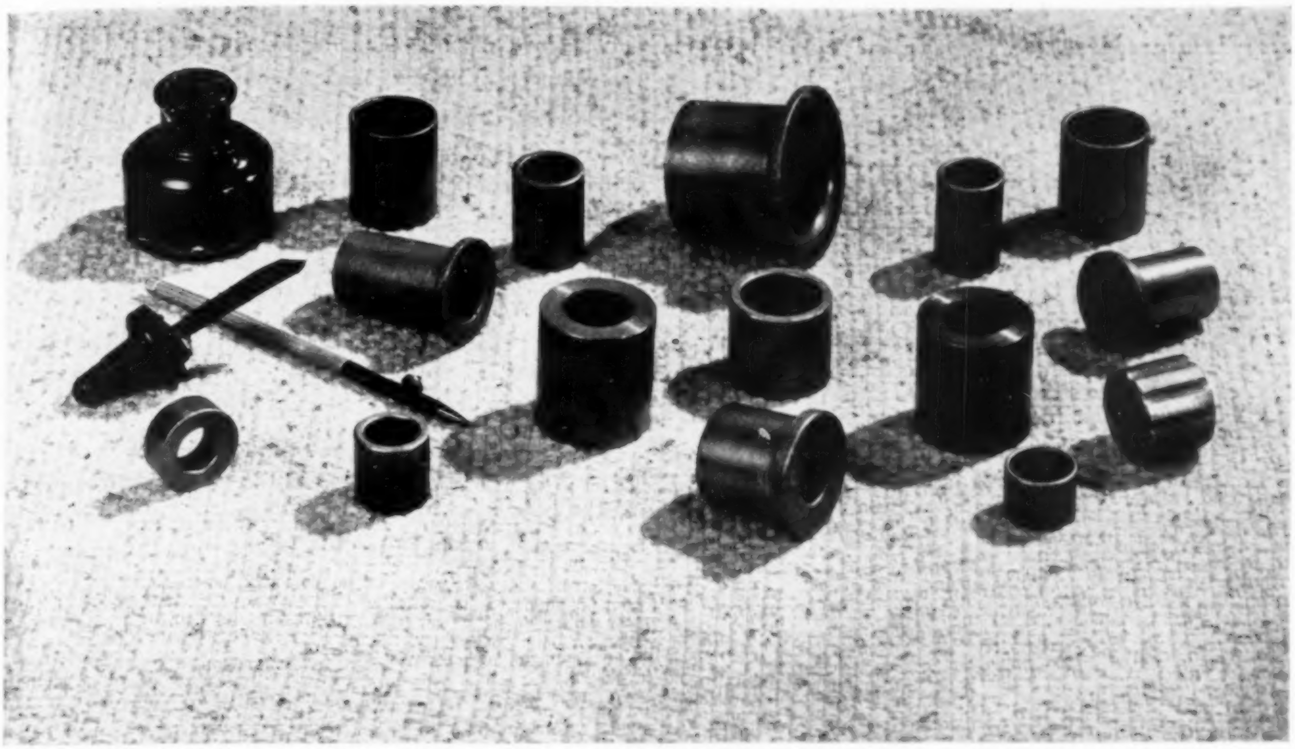
After washing, drying and rubbing, the powder is carefully separated into sizes by a series of screens and bolting cloths of closer and closer weave. The very finest particles are removed and classified by an ascending air current — the same principle the threshing machine uses to separate the wheat from the chaff.

Powder is Closely Graded

By such methods as indicated above the fabricator is furnished metal of the highest purity in rough, angular fragments, with particle sizes either within close limits, or conforming to specified screen analysis between 100 and 500 mesh.

Such metals are ready for compression, either as an individual metal, or as a controlled mixture of two or more. Subsequent heat treatment converts the pressed pellet into perfect alloys or sintered compounds, as desired. It is possible in this way to make tungsten ingots (ready for swaging into fine wire), the common brasses, bronzes, and monel metal, stainless steel and chromium-nickel-iron alloys, and — even more interesting and probably more valuable — mixtures of metals which could not be poured out of a melting pot. Instances of the latter are metals with large differences in melting points such as copper and tungsten. Mixtures of metals and non-metals (such as of tungsten carbide and cobalt, or of copper and graphite) may also be fabricated in this manner.

In the manipulation of such powders the metal worker has borrowed many ideas and much equipment from the drug manufacturer. The fastest presses, in fact, are overgrown pill-making machines! In order that exact quantities of the powder may each time fill the same mold, the loose material is fed after trickling down a succession of inclined planes, and enters the cavity at an exact velocity. This regulates the factor of "self packing"; one stroke from



Typical "Oilite" Bearings and Bushings. A hard bronze made of powdered graphite, copper, and tin. Oil fills the 30% voids. Courtesy Chrysler Corp.

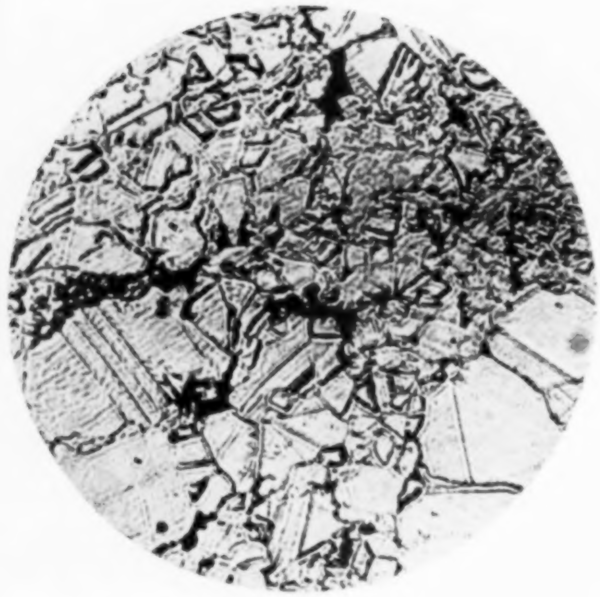
the dies of given pressure will thereupon produce a pellet of correct density and size (exact to 0.0005 in.). Heat treatment or sintering will cause small changes in size, but these can be allowed for in advance.

The amount of compression, which is ordinarily more than 5000 lb. per sq.in., determines the density of the finished material. Another factor is the screen-size analysis of the particles. Both these factors are under control. (As high as 250,000 lb. per sq.in. has been used to produce copper slightly denser than busbar metal. Powerful hydraulic presses, rather slow in action, are of course necessary for large pieces and heavy compression.) Subsequent heat treatment will give strong, coherent metal parts ranging, as desired, from $\frac{1}{3}$ to $\frac{4}{5}$ the theoretical specific gravity of the alloy. The difference is of course due to microscopic voids. The finished article is a metallic sponge.

Far from making it a useless curiosity, such a property is responsible for the largest use of powdered metal — namely, for oil-less bearings (more properly called "capillary lubrication"). These have been installed for several years in small electric motors for fans and other equipment where expert care cannot be insured. Electric clocks and domestic refrigerators have also used great quantities of them. One of the leading automobiles last year had eight bearings of this sort known as "Oilite"; the service was so satisfactory that the 1932 models have nearly a hundred of them in spring shackle bearings, steering gear bushings, clutch pilot bearings, chassis spring inserts, generator bearings, and water pump bearings.

Manufacture of Oil-less Bearings

A typical oil-less bearing is made of 90 parts of copper, 10 parts of tin, and 1 to 4 parts of electric furnace graphite. The loose mixture is pressed into the form of a sleeve; its coherence is then such that it can be handled with considerable freedom. Heat treatment merely involves dipping into a cyanide pot; time and temperature are regulated so there is a true welding action at the multitude of points where metal comes into contact with metal. (This is so effective that subsequent fracture under test or overload will cross through the middle of the original grains rather than at the welded contacts.) The hot bearing is then quenched in lubricating oil, and left submerged until the



Uniform Copper-Zinc Solid Solution in Synthetic Brass Made of 88 Parts Copper Powder and 12 Parts Zinc Powder. Compressed into small disk at 50,000 lb. per sq.in., annealed 2 hr. at 1300° F. in reducing atmosphere, cooled and re-pressed at 50,000 lb. per sq.in. Cavities (black areas) do not prevent ample metal-to-metal contact

capillary pores are completely filled with oil.

The amount of oil which can be absorbed obviously depends upon the specific gravity of the metal mass, and this (as indicated above) is regulated by the particle size of the constituent powder and the pressure. Very satisfactory bearings for heavy duty contain from 30 to 40% oil, by volume. Bearings have been made with crushing strength up to 75,000 lb. per sq.in. Oil exudes from the pores at these high pressures, and consequently furnishes lubrication to a journal which would otherwise be running dry and hot.

Even though these bearings have a source of oil within them, they are mostly used to regulate a gravitational supply of oil to important journals. Such bearings, properly lubricated, approach closely the efficiency of the best ball or roller bearings. Especially is this true when the machine first starts; most of the wear in an old-fashioned solid "box" occurs before the oil is warm and a good film established. In the new spongy bearing metals an adequate supply of oil is contained in the texture of the journal itself.

Enough has now been said so the reader can easily appraise the following advantages of the new method of fabrication with powdered metal as raw material.

Advantages of Compressed Metal

1. Porosity of the final mass is under control. Stainless alloys have been produced of half the specific gravity of rolled steel.

2. Grain size is under closest control.

3. Metal of highest purity is produced. Iron alloys substantially free from sulphur, phosphorus, carbon, and nitrides open new opportunities for specialists.

4. Alloys of constant composition are produced. This is very important for electrical alloys. In the telephone industry, for instance, a 90-10 bronze and a 70-30 monel are made of powdered metal to a uniformity entirely unapproachable by foundry methods. Contact points made of silver and molybdenum and silver and nickel are other examples.

5. Alloys and mixtures of metals, immiscible in the liquid state, or having great differences in melting points, are produced. Instances are lead and copper, copper and chromium, copper and tungsten, and copper and molybdenum. The latter are useful for welder electrodes or switch contacts handling heavy currents; the copper gives good conductivity for electricity and heat; the tungsten lends hardness against wear and refractoriness against high temperature softening.

6. Mixtures of metal and non-metal may be effected. Examples are tungsten carbide and cobalt (the carbide cutting tools); copper and graphite mixtures for current collecting brushes on dynamos and motors.

7. Size of the completed article may be held to close limits. The dies may be cut to any desired degree of accuracy and the presses refined in design. Restriking or coining may further increase the precision of the articles. In this regard they compete with the very best die castings.

8. Manufacturing losses are very small. Compare them, for instance, with the many operations in conventional fabrication: Slagging losses during melting; the crop and oxide loss of rolling; the flash or trimming loss of forging or stamping — frequently only half of the original metal appears in the finished part;

the rest must be reworked. None of these losses occur in the pressing of powdered metal, and for that reason the raw material may carry a considerable premium and the article's final cost still be competitive.

9. Useful bi-metals may be manufactured. A rectangular mold may be three-quarters filled with iron, the surface leveled, and the remainder filled with nickel. Pressure then converts this to a composite ingot, heating and rolling produces a thin plate or sheet — part iron, part nickel — perfectly welded together. In a similar manner composite tools may be manufactured with a steely strong base and a layer of excessively hard alloy on top. Or a steel bearing shell may be lined with a thin layer of babbitt or bronze.

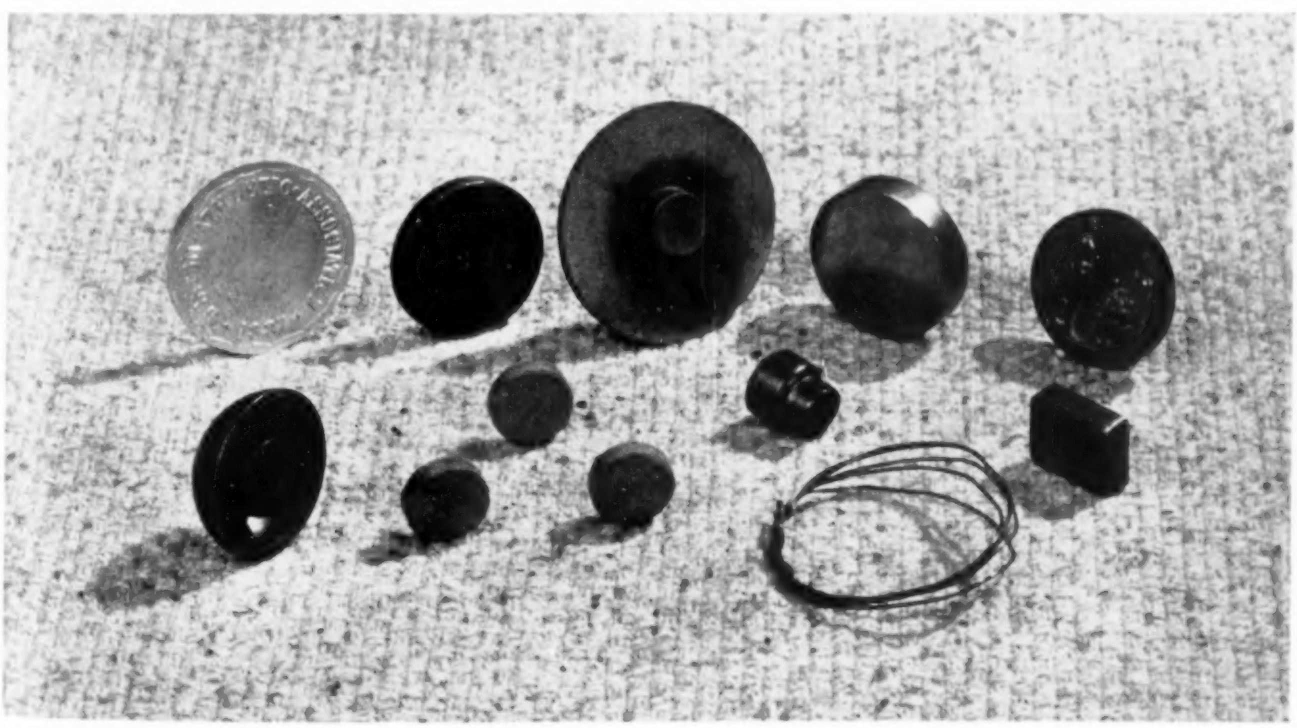
10. Considerable saving in valuable raw material may be made. Sterling silver table ware, for instance, may be pressed and have a density hardly half that of the same ware stamped from metal strip.

If a very dense alloy is needed, it can be had either by extra heavy pressure in the dies, or by a correct program of mechanical work and heat treatment. Consolidation may be done by swaging, rolling, drawing, or forging — any of the common operations now done on cast ingots or bars. It should be emphasized that the metal parts in process are never fragile. A bar of copper directly from the press has a metallic ring. After heat treatment it is quite tough and ductile, even though its specific gravity is low.

The heat treatment of the pressed article depends upon the constituent metals. Usually it is at about two-thirds the melting point of the most fusible. At any event, the heat and time must be sufficient to cause a substantial amount of diffusion of one metal into the other. Likewise the air must be excluded, or the metal heated in a mixture of reducing gases. If complete diffusion of one metal into another is required, as in synthetic iron-nickel magnetic alloys, the time and temperature must be appropriately chosen; original fine grain will reduce the necessary annealing time, but heats are moderate and inexpensive from the standpoint of cost of thermal units.

One notable limitation now characterizes the commercial application of the above ideas, and that is the matter of size. As the diameter or area of the article increases, the total amount of pressure required *(Continued on Page 80)*

A Wide Variety of Articles Made From Powdered Metal. Upper center is porous bronze interleaf for automobile spring. Medals are of sterling silver and bronze. Medal discs are brass and german silver. Below are two small bearings, three copper tablets for chemical catalysis, a copper-carbon motor brush and some copper-chromium wire



Forging dies made from master types

By R. H. McCarroll

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Ford Motor Co.
Dearborn, Mich.

DIE TYPING as practiced by the Ford Motor Co. consists of forcing a hardened master into a block of steel. The process is carried out in much the same way as a signet ring is used to make an impression in wax. Thus, in order to type a forging die for a lever with a ball seat, such as shown at the lower right of the assembled group on the opposite page, it is necessary to make a "master type" or positive copy of the required shape, plus the amount of shrinkage that would be encountered when the die cools, plus the amount of shrinkage of the hot forging to be made in the die.

These types are cut by a tool maker of the regular die block steel used for hammers, having the following composition: 0.47 to 0.55% carbon, 0.50 to 0.60% manganese, 0.60 to 0.75% chromium, 1.50 to 1.75% nickel, 0.10 to 0.20% silicon. Sulphur and phosphorus must both be lower than 0.03%.

To make small dies of this sort, pieces of the regular die block steel, cut to suitable size, are heated to 1700° F. in a lead pot and placed in a retaining ring. The master type has previously been mounted in the upper ram of a 90-ton press. The retaining ring holding the heated billet is then pushed into place on the press bed directly under the type and the press is tripped. This impresses the correct shape in the top of the die block, which is immediately covered with fine charcoal or cast iron chips to avoid oxidation. When it is cool it slips out of the retaining ring.

Several dies can thus be made quickly in one set-up. Some varieties would be restruck for close tolerance before mounting.

Slightly different procedure is desirable for such dies as the star punch for the gasoline gage nut. Master type then consists of a ring with a star impression worked into the center just enough larger than the punch required to allow for shrinkage. The master would be placed on the bottom of the press, the steel blank heated in the lead pot and placed upside down on the master type, and the press (having a flat upper bed) tripped, thus driving the blank into the master die.

The above conveys the principle used for all the lighter dies.

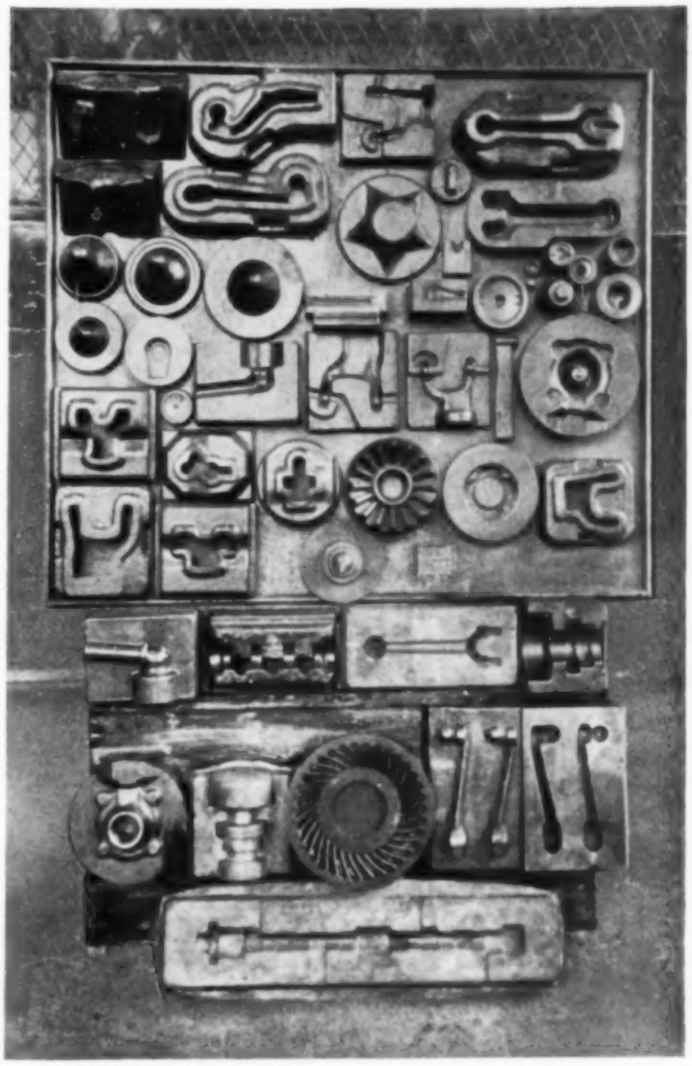
Large forging dies, Ajax dies and trimming dies are made on a 2500-lb. steam hammer. For this work the master type consists of two mating blocks, one for the anvil, one for the hammer head. In the lower one is machined a smooth bottomed cavity, the depth of which is approximately half the thickness of the die to be made. The upper one has a similar cavity with the

exception that the shape desired is engraved or embossed in the bottom of the cavity mentioned.

The purpose of this cavity in the two typing blocks is to retain the heated metal when it is struck and to cause it to flow up into and around the depressions in the master, filling in sharp corners and various intricate places. Sometimes, where difficulty is experienced in filling corners or small projections, it is necessary to drill vent holes in the master type, thus allowing the trapped gases to be compressed into these pockets or vents without retarding the flow of the metal.

Ajax die blocks are straight 3½% chromium steel (carbon 0.60 to 0.75%, manganese 0.30 to 0.40%, silicon 0.10 to 0.20%) and ordinarily the billets would be heated to 2100° F. It is essential that the temperature be correct and the same for all dies typed in any one master, as this master is made to allow for a certain shrinkage, and if the temperature is allowed to vary, dies of incorrect size will be produced.

Trimming dies are made in much the same way; the master pierces the correct opening. The bottom of such blocks must then be squared. Cutting edges are filed to template before hardening.



Assortment of Forging, Stamping and Trimming Dies. Shapes are pressed into hot metal by master types, some of which are shown

A most important factor when heating the blocks before typing is to avoid scale. In small pieces this is done by heating in a lead pot. When treating big blocks the atmosphere in the heating furnace must be controlled or the billets must be protected from oxidizing gases. No scale can be tolerated on the face of the die block which receives the impression, else it would be forced into the surface and cause an unwanted depression. The cavities or projections in the dies, in other words, are finished to precise shape in the typing, and no machine work or other cutting is permitted. (It is only necessary to square up the bottom and sides after typing, to fit the tapered holder.)

The method used at the River Rouge plant of the Ford Motor Co. is to grind the top side of the billet to be sure to remove all decarburized material which might have resulted from rolling or forging in previous manufacturing operations and cover it with common salt (sodium chloride) as soon as it is placed in the furnace. As the block comes up to heat and reaches 1450° F. the salt melts but a protective film remains on the hot steel even up to forging temperature (2100° F.). This is easily scraped off just before the actual typing operations.

Not only has the cost of making and mounting simple forging dies been decreased to a fraction of what it once was, but the typed dies produce about 25% more forgings. This is probably due to the extra work and grain flow produced at the working surface. Dies are seldom discarded due to breakage, but to slight warpage.

A master type is good for 200 to 400 forging dies. Where a great number of one kind of dies are consumed and the typing master must be replaced frequently, it has been profitable

to make a "Master-Master," or a master die which is used to type the master type, which is in turn used to type dies. When this is done a set of master hammer dies are made which resemble the forging dies that are to be ultimately made, and differ only in that they are three shrinks larger than the part to be produced. One shrink will occur when the master type is made, another when the master type is used to make the forging die, and the third occurs in the forging itself.

It is seldom necessary to make the forging die the full size and depth desirable for hammer or anvil. Sometimes an insert can be typed and fastened into larger blocks by frictional engagement, either by using slightly tapered sides on the insert and driving the same into the block, or by expanding the block by heating to 850° F., driving the insert into the cavity, and allowing the larger block to cool and contract. A shrinkage of 0.0025 in. per in. is satisfactory. There is no chance of coming loose while in use.

Such holder blocks should be carefully checked for growth after, say, the tenth use. If they are then found to be too large they can be heated and pressed back to shape. Their life is therefore indefinitely long.

Forging a Drop Forging Die in a Steam Hammer

IT IS told that Mr. Kettering, when he was intent on devising some new method for varnishing automobile bodies, asked several paint experts to consider the matter. When they reported that the usual time of two weeks might possibly be cut down to two days, they were mortified to find that he had fixed his mind on two hours. And that's about what he got before he was through with them!

Some day some equally persuasive and resourceful man is going to say to himself, when viewing the maze of lathes, planers, shapers, milling machines and broachers that now-a-days is required to make almost any high duty machine part, "There's altogether too many machine tools here," and proceed forthwith to do something revolutionary.

Several ways have been pioneered already. Few works managers are proud of operations that take a heavy cut into sound metal. The whole die casting industry is built on its ability to furnish parts that require little or no machining. Many a detail has been redesigned for pressed metal because it saves much of the finishing. Drop forgers are being held to such close limits, to minimize the amount of subsequent cutting, that especially accurate presses are being manufactured for the purpose. Restriking and coining are also frequently done.

Advances in the direction of machine-saving may be seen in almost every progressive shop. An example is the work on connecting rods done by the maker of one of the high quality automobiles. Connecting rods are important members, subject to complex and speedily varying loads. Owing to their rapid motion, the problem of balance is important, so important in high speed aero engines that rods are machined all over and carefully balanced in a set. This motor car manufacturer avoids this expense by precision work in the forge plant.

At that place the connecting rods are made to fairly close dimensional limits, then fully heat treated and sand blasted clean of scale.

Editorial

Next the rods are restruck between dies in a board drop hammer the required number of blows until the faces of the dies all but touch. This not only sizes the rod but takes any warp out of it, so the end faces remain parallel after the subsequent operations. Next the rod is put through a coining press which corrects the distance, face to face, on either end to a few thousandths. Finishing can then be done by a surface grinder.

This combination of hot and cold working operations has saved a notable amount of machine work. Results are so satisfactory, in fact, that machine-saving ideas may become as profitable in the next decade as labor-saving devices have in the past.

IT HAS been frequently remarked that the cleanliness and smoothness of the part before it enters the plating tank has a pronounced effect on the durability and corrosion resistance of the deposited coating. There is an even greater incentive for such care before chromium plating, for the action of the bath is seriously deranged by impurities.

Mr. Udy, in his article in the last issue, emphasizes the fact that the ratios between trivalent chromium, sulphate radical, and chromic acid must be kept within definite limits if a chromium plating tank is to operate satisfactorily. Correspondence with the author brings out the additional fact that the amount of trivalent chromium will increase beyond workable limits if the bath is fouled with iron, nickel, copper, or other metals or organic matter. As a fresh bath made up of pure chemicals picks up more and more of these impurities, the voltage required for a constant current density also increases.

On starting the bath with 32 oz. per gal. of chromic acid and 0.40 oz. per gal. of sulphuric acid, the ratio of chromic acid to sulphate is the prime factor controlling the operations. After the bath has acquired a certain amount of impurities, the trivalent chromium increases and becomes the controlling factor. Good plating, in Mr. Udy's opinion, requires a ratio on the order of 15 of chromic acid to 1 of trivalent chromium.

From a theoretical standpoint it is interesting to note that the ratio of trivalent chromium and sulphate radical in baths in good condition does not conform to that of any known chromic sulphate. It is probable, therefore, that some of the chromium exists as free ions, perhaps due to the solution of chromic hydrate, $Cr(OH)_3$, in chromic acid. The hydrate, on solution, would be ionized into positive chromium and negative hydroxyl ions, and it is from these ions that deposition of metal and gas on cathode and anode respectively takes place.

It is indeed fortunate for commercial operations that the sulphate radical and the lead anodes control the production of trivalent chromium; otherwise a constant bath could not be secured. The only guard against departure from a good operating ratio (other than adding sulphate) is intelligent attention and cleanliness. Impurities must be kept out of the bath, for once there they are difficult if not entirely impractical to remove.

MACHINABILITY is something we all talk knowingly about, but do little. Tool trouble is here today and gone tomorrow! While one department is explaining why its operations are not to blame, it vanishes. But in its trail are a lot of burned or broken cutters, parts with second grade finish, and lean pay envelopes.

One recent occurrence of this sort lasted a couple of months and ran up a bill of $8000 or $10,000. The different thing about it was that some intelligent people resolved to find out why, and the leading article in this issue by Messrs. Cederleaf and Sanders is one result. This work will put all metal workers in their debt, for it

Editorial

shows how every operation from forge to final inspection has been improved. Using alloy steel of the same analysis, the wear on dies has been reduced, the annealing cycle shortened 40%, tool speeds and feeds increased 11 to 60%, production increased 50 to 400%, tool cost reduced nearly half, and dimensional tolerances and changes in dimension after hardening reduced materially. The net result is a lighter gear which is stronger, resists surface pitting better, has a longer life, and costs less.

Certainly these are proper rewards for an intelligent research.

Cederleaf and Sanders also poked about in the preserves of another metallurgical sacred cow, to their everlasting credit. We refer to the matter of flow lines or "fiber" in the forgings. It would be interesting to trace its trail back through the literature; undoubtedly it would take us to early Sheffield and ancient Damascus and land us in the prehistoric home of Tubal Cain himself. Few indeed would we find en route who had controlled this fiber; it was in the steel or it wasn't and that was that.

An upset bar, such as a forging for a cluster gear, is a fine place to observe that the undisturbed bar has little or no fiber, but the upset part has. This one fact is enough to explode the idea that fiber dates back to the ingot. Or, to put it another way — segregates, slag and dirt in the ingot may be rolled out into stringlets and produce seamy steel, but another kind of fiber is introduced into clean, sound metal by hot or cold work.

When the men at Muncie observed that the etching figures became less pronounced if these forgings were restruck or compressed and the specific gravity of the most fibrous metal might be 6% less than the original bar and that its hardness might drop to B-41 from a normal B-67, they naturally concluded that the forging operations were "opening the grain" or producing numberless internal cavities, either too small to be seen on a machined surface or smeared over by flow of metal, until the strong acid ate into them. Whether this plausible theory will stand ultimate scientific analysis, it has the merit of fitting the observed facts, and of leading into a profitable revision of shop practice.

At first glance, a forging operation (especially drop forging in dies or upsetting) should compress the metal from all sides and thus should raise the specific gravity of the metal rather than lower it. All workmen know, however, that it is relatively easy to open internal cavities by severe rapid reduction. Modern methods of rolling seamless tubing from solid billets depend on this very fact. This being admitted, one next asks, "What is the internal structure of metal when the work is stopped just before visible cracks open?"

Cederleaf and Sanders reply that a common stage between a sound bar and a forging with a gross internal cavity is a metal mass of variable density — solid where compression has been high, shattered where shear stresses have caused rapid movement of the metallic grains past each other. Furthermore that these shattered zones are hard to machine — the tool chatters and dulls rapidly because it has the triple duty of closing the cavity ahead of its edge, starting a cut and cutting. Some of the tool trouble may be due to poor microstructure — presence of considerable excess ferrite — for these shattered zones, curiously enough, do not respond uniformly to annealing. (An apparent contradiction is that gray iron and malleable iron, full of cavities, will machine easily, but the cavities are filled with graphite, a fine lubricant.)

Obvious remedies for fibrous forgings are to redesign the dies so metal will be moved less abruptly and so the part rather than the flash will get the compression. The bar should also be hotter and more plastic. There's nothing very difficult or abstruse about these correctives. It is also comforting to know that the more machinable forgings are made by this method at a higher production rate and wear the dies less.

Furnaces & hammers for forging aluminum

By J. B. Nealey
American Gas Association
New York

WHILE THERE ARE several methods of making products from aluminum, the best physical characteristics are brought out when they are worked, hot or cold, just as for iron. To pursue the analogy further, these physical properties are greatly augmented when certain alloys of aluminum are used, properly heat treated. Hence the forging of aluminum articles has been confined almost wholly to the so-called strong alloys.

It is perhaps opportune to recall that the first hardened aluminum was a German product, and a series of such early alloys under the name duralumin was responsible for the pre-War development of rigid dirigibles. From this group of alloys one containing 4% copper, 0.5% magnesium, and 0.5% manganese is now more or less standardized for thin sheet or strip to be formed into articles or structural members requiring lightness and strength.

Such an alloy has been used to a considerable extent for forgings, and is even yet so used. It is quite hard at the forging temperature and articles made from it are limited in shape, size, and degree of reduction. For that reason the research laboratories of the Aluminum Co. of America, shortly after the War, developed two other alloys of superior forgeability, and these have been in production since 1921.

One of them is known as 25S. It contains about 4.4% copper, 0.8% silicon, and 0.75% manganese. It forges much more easily than duralumin, but still is harder at 840° F., its forging temperature, than low carbon steel is, under the hammer at 2350° F. Whereas quenched duralumin age hardens spontaneously at room temperatures, 25S must be mildly tempered, whereupon it acquires equivalent tensile properties, namely, 58,000 lb. per sq.in. ultimate and 20% elongation. Its other physical properties are listed in a data sheet published in METAL PROGRESS for November, 1930, and the microstructure is illustrated in another published last December.

The other common forging alloy, called 51S, is even softer under the hammer, having the workability of pure aluminum. It contains no copper, 1.0% silicon, and 0.6% magnesium. While it hardens spontaneously after a solution heat treatment, the maximum strength of 48,000 lb. is quickly reached by a mild precipitation treatment. Intricate and severely deformed forgings are made of it, as are also lightly stressed parts and hardware requiring a high polish.

A more recent addition to forging alloys should also be mentioned: "Super-duralumin," which is 25S plus 0.35% magnesium. Its ultimate tensile strength in the fully heat treated condition is 65,000 lb. per sq.in. with 12% elongation in 2 in., which (since it retains hardness at moderately elevated temperatures) would cause its selection for parts subjected to especially severe duty.

Forging alloys are under constant study, and compositions with improved workability and physical properties may confidently be expected.

While forging practice is much like that used in steel forging, it has some important points of divergence. In the first place, it requires from 20 to 30% more power to forge 25S than it does the ordinary steels, although, as noted above, this varies with the other analyses. Aluminum does not flow readily. In wrought iron a weld can be made and sometimes a cold shut will flow together but never in aluminum. These and other difficulties, however, have all been overcome by carefully controlled methods.

As in steel forging, the billets are first reduced from the cast ingot at least 80%. Recent practice at the Cleveland plant of Aluminum Co. of America has controlled the grain flow so as not to let any of the lines or fibers kink or run out at the edges of the forging and thus form weak points that may subsequently fail in use.

In designing forging dies the radii must be larger and the impressions must be highly polished. A shrinkage of ⅛ in. per ft. and a draft of 10% are allowed. These dies are usually of chromium-nickel steel, hardened after cutting, and are made with stock impressions, fullers and edgers on the right and left margins for working the hot billets and bar stock into a rough form to fit the die — an item of considerable importance in aluminum forging. Most dies also have a generous gutter outside the flash to receive the surplus metal. Commonly

Main Aisle in Forging Shop for Aluminum Alloys. Board hammers at right rear

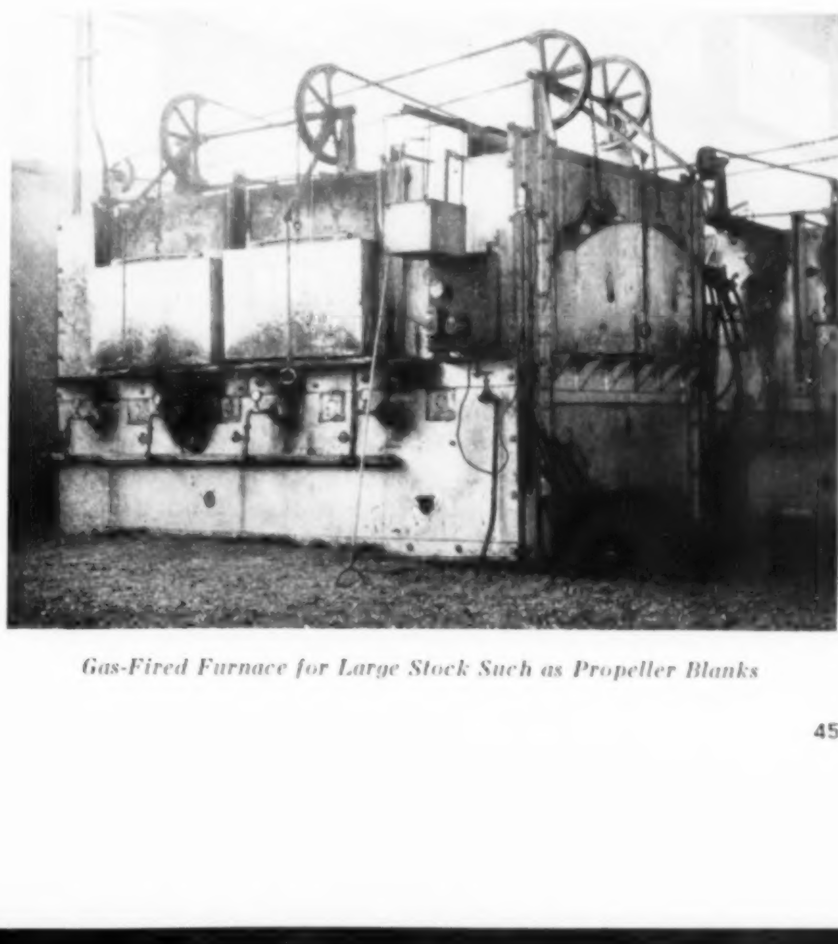
Forged Crankcases for Radial Engine Show Intricacy Possible With Aluminum Alloys

it is necessary to trim and restrike the forging one or more times before it is within tolerances of, say, 0.02 in. oversize. Straightening and coining to size of ±0.003 in. (if specified) are usually done after solution heat treatment and before precipitation heat treatment, as the metal is then in its most plastic condition. Flash is frequently trimmed by a bandsaw, when the number of pieces does not warrant the expense of a die.

Steel forging practice is usually thought of as being 90% mechanical and 10% metallurgical, but the reverse is true in forging strong aluminum alloys. This calls for modern furnaces utilizing a fuel which can be exactly controlled to produce the proper temperature and the correct furnace atmosphere. Temperatures required are low — below the visible radiations, so heating must be almost entirely done by convection, or contact with a circulating medium only slightly hotter than it is desired to heat the metal. For these and economic reasons gas is used for heating most of the forging furnaces in this plant. Allowable temperature range for forging 25S is between 800 and 840° F. If the heat drops below 775° die wear and hammer strain become excessive, while hot shortness appears above 850° F. Hence the stock must be heated accurately, checked with a pyrometer, and returned to the furnace for reheating when it has cooled through a relatively small interval.

The forging division at the Cleveland plant contains 12 steam hammers ranging in capacity from 1500 to 18,000 lb., three board hammers from 1500 to 3000 lb., and one upsetter. Two of the steam hammers are of the open frame type. Many airplane parts are made here, including propellers, engine crankcases, connecting rods, lugs, brackets and also machine parts ranging from half-pound pieces up to locomotive side rods weighing a ton each.

Serving these hammers are 16 forge furnaces fired with gas fuel, of different types and sizes, as dictated by the necessities of the work for which they were designed. The one in which propeller stock is heated is 10 ft. wide, 8 ft. deep, and 7 ft. high. It has a wide door at one end and three narrow ones in front, all with hydraulic lifts. Firing is accomplished with 15 gas burners, five in front under-firing



Gas-Fired Furnace for Large Stock Such as Propeller Blanks

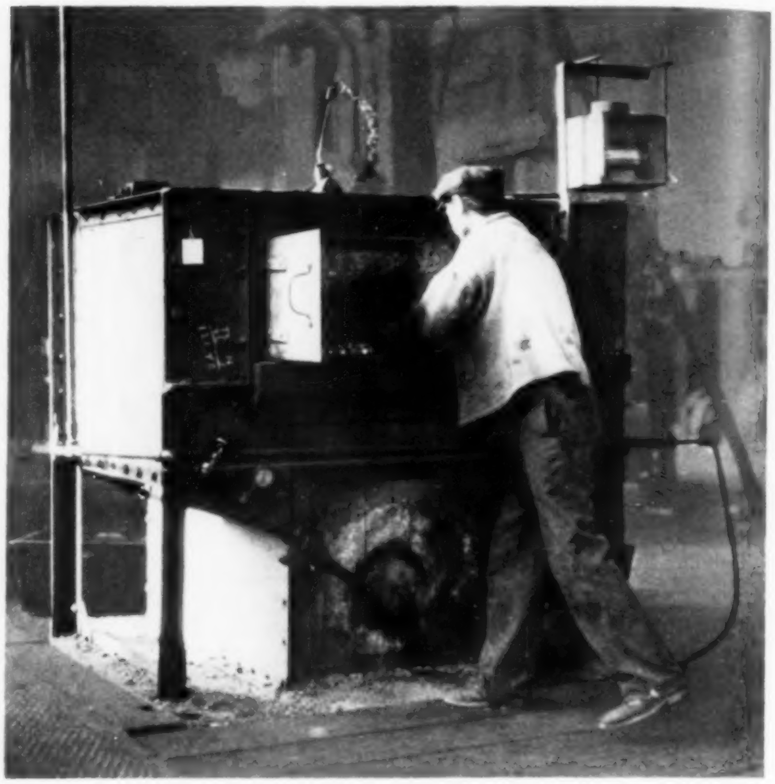
the hearth, five in the rear underfiring the hearth, and five in the rear firing against the arch. These burners are all fed from one manifold which is run around the furnace on three sides, carrying an air-gas mixture.

At other furnaces where the air and gas pipes are parallel, an automatic device controls the flow of air and gas simultaneously through the movement of two interlocked valves, one cut into the air line and one in the gas line. These valves are connected by a single crossbar, so that the movements of both are identical; they are moved by a connecting rod to a motor-driven worm gear. The motor is intermittently energized through contacts made on a multi-point switch by an expanding element pyrometer, one end of which protrudes into the furnace. When the furnace temperature is too high, contact is made on one point and the motor closes both valves, shutting off the fuel supply to the burners; conversely, when the heat has dropped the fuel flow is restored. Valves are so proportioned that the volume relationship of air to gas for proper combustion is maintained at all stages of opening.

All furnace brick work is encased in steel. In size the furnaces range from the large one quoted above to small ones for the light work. Another type is 10 ft. long, 5 ft. wide, and 6 ft. high; heat is supplied with four gas burners on each side, half of which fire under the hearth and half over.

One furnace of a semi-muffle type is interesting. It has a combustion chamber apart from the furnace proper and this is placed below. It is known as the T-type. The combustion chamber is 5 ft. long, 3 ft. wide, and 2 ft. high, while the furnace is 5 ft. long, 5 ft. wide, and 3 ft. high. It is heated with two gas burners, one firing into the front and the other into the back of the combustion chamber, the hot products of combustion rising up around the hearth into the heating chamber. These burners are equipped with venturi tubes for automatically proportioning the gas and air mixture by which the furnace atmosphere can be controlled.

T-Type Furnace With Combustion Chamber Located Below Hearth



The other furnaces closely resemble those described and vary only in size, number of doors, number and position of the gas burners, and kind of temperature control.

Finally, the completed forgings are heat treated and artificially aged to impart the maximum physical properties obtainable in the alloys. The style of furnaces and the operations were described by G. D. Welty in Metal Progress last June. First, or solution heat treatment, is done at about 950° F. (the exact heat depending on the nature of the alloy). Quenching is frequently done in 15% caustic soda in order to clean the forgings of oxide and dirt. After washing in water a 3-min. immersion in 15% nitric acid imparts corrosion resistance. Another washing precedes restriking or coining, and finally the parts are aged in large tanks heated to about 280° F. by injections of superheated steam.

Figures for strength are merely illustrative. By proper selection of analysis and heat treatment, a wide range of specifications can now be met by aluminum alloy forgings.

Resonance of rings is no test for hardness

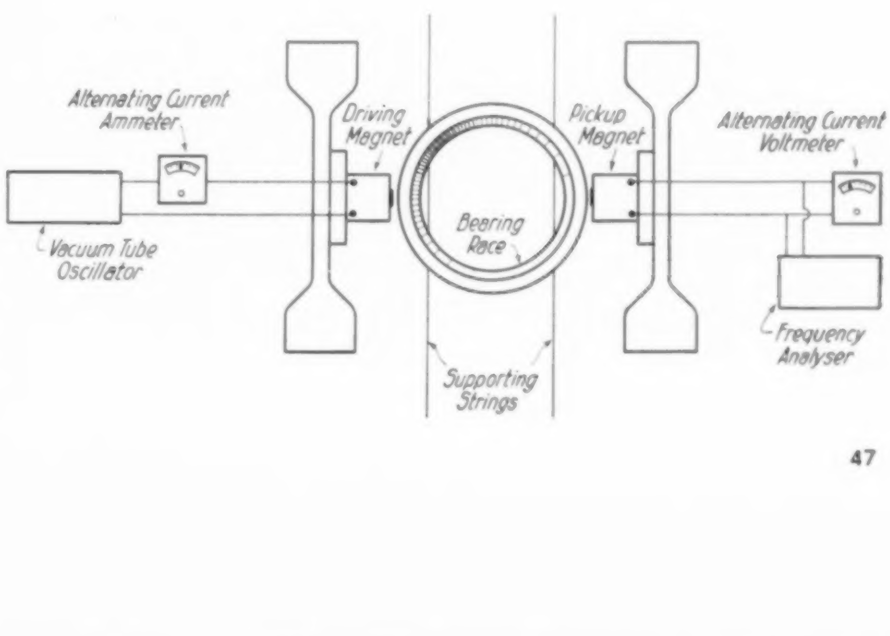
By H. B. Vincent
and F. A. Firestone
Dept. of Engineering Research
University of Michigan

A FEW MONTHS AGO, being approached by an experimenter who claimed to have developed a process for detecting soft spots in bearing races, the Timken Roller Bearing Co. of Canton, Ohio (which sponsors numerous researches in the University of Michigan's laboratories) referred the matter to the authors for investigation. The method proposed excites the race at its natural or resonance frequency and the claim was made that the presence of a small region deficient in hardness would so alter the natural frequency that parts having such defects might be recognized thereby and rejected in production.

If a roller bearing race is suspended from a cord in such a manner that it is free to vibrate and is given a light stroke with a soft hammer, it produces a ringing sound. The pitch of this musical tone is the resonance frequency mentioned above.

In order that such a test should be satisfactory, it is necessary that the variations due to defects should be larger than the fortuitous variations among good parts. To determine what this fortuitous variation would be, twelve races were chosen and the natural frequency of each was determined. Case hardened cups having an outside diameter of 2.8593 in. + 0.0010 in. — 0.0 in. were selected for the experiment, each piece first being tested in numerous places with a file to insure that none of these samples had soft spots on the operating surfaces.

Cups were placed in turn in the equipment shown in the sketch. Two light cords stretched



Diagrammatical Plan of Apparatus for Testing Resonance Frequency of Ball Races. Cup or cone rests on the two taut strings, vibrated magnetically, and the result measured by the frequency analyzer

in a horizontal plane serve to support the race between two magnet systems. One magnet, carrying in its winding a current from a vacuum tube oscillator, serves to excite in the cup a vibration whose magnitude increases sharply to a maximum as the driving frequency approaches the frequency of resonance. Since the wall of the cup acts as an armature for the second magnet, the voltage generated in its winding for the condition of resonance will show a maximum response on the vacuum tube voltmeter connected thereto. The frequency at which this phenomenon occurs may be determined by means of the frequency analyzer (or by various other suitable apparatus). Although no experiments with other supports were performed, it is certain that the cords, being comparatively light and compliant with respect to the race, would produce a negligible change in its natural frequency.

Results of Tests

While a larger number of test pieces might yield a somewhat wider distribution of results, the twelve parts tested gave a variation of 1.2% between the highest and lowest resonance frequencies observed as described above.

To determine the alteration in natural frequency which might be expected if a region deficient in hardness is present, one-quarter of the circumference of one of these cups was softened in a flame and allowed to cool to room temperature. Measurements showed that the softening of this section had increased the natural frequency by 0.46% while tests with a file indicated that the part heated had lost its surface hardness. Another cup similarly treated showed an increase in resonance frequency of 0.521% when one-third of its circumference was softened.

It is obvious that these parts would be very unsatisfactory for use in a bearing yet the variations observed due to softening even these large portions of the piece were small compared with the random variation in natural frequencies among good races. Hence it seems that this process has no merit for routine inspection of such parts in production.

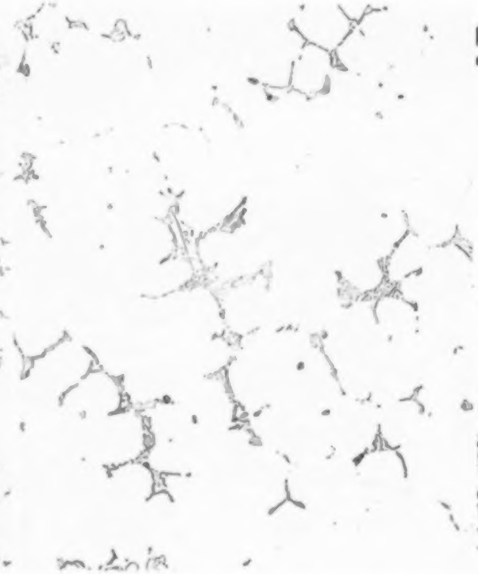
Neglecting tolerable errors in geometry, the method might measure the average hardness. However, we have demonstrated that it gives very little indication of the distribution of hard and soft regions. In a structure such as a bearing race, made up of a relatively soft and bulky low-carbon core enclosed in a quite hard and relatively thin carburized case, the average hardness is largely dependent on the carbon content of the core. The wearing quality of the part depends not upon the average hardness of the bulk but on the hardness and uniformity of the case. The experimental failures quoted above might therefore be predicted from purely philosophical conditions.

Courtesy The Timken Roller Bearing Co.

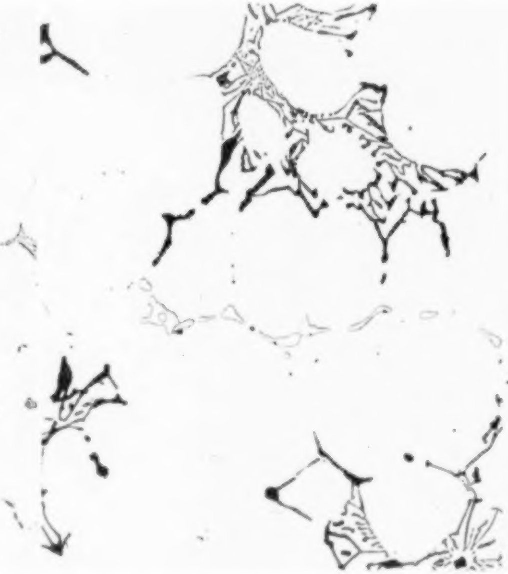
High Strength Aluminum-Copper Sand Castings

Aluminum Company of America's No. 195 Alloy — Typical Composition: 4.3% Copper, 0.6% Iron, 0.8% Silicon

As Cast. 100 ×. Etched with an aqueous solution of 0.5% HF. The light outlined constituent is $CuAl_2$. The darker constituent is an iron complex, the composition of which varies with the casting conditions



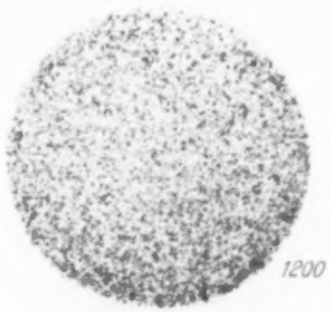
Heat Treated. 100 ×. Etched with an aqueous solution of 0.5% HF. $CuAl_2$ is entirely in solution. The dark, outlined constituent is the iron complex

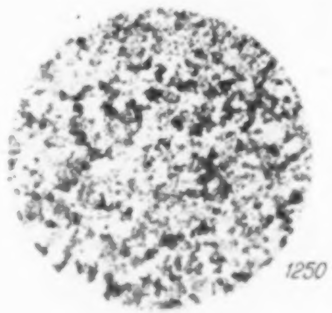


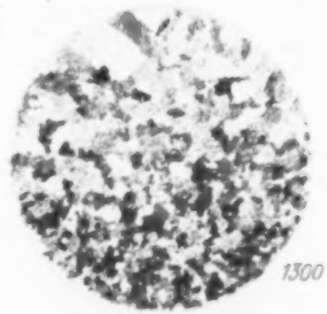
Partially Heat Treated. 500 ×. Etched with 20% solution of H_2SO_4. $CuAl_2$ is light and outlined. Black constituent contains Fe, Si and Al with perhaps some copper

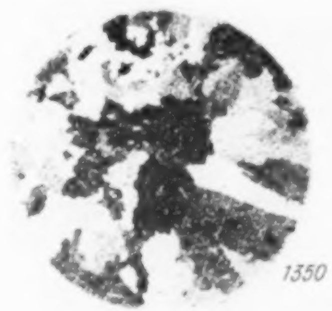
Heat Treated. 500 ×. Etched with a solution of 1.5% HCl, 1.0% HF and 2.5% HNO_3. Shows the duplex nature of the iron-bearing constituent, resulting from a reaction between solid $FeAl_3$ and the liquid alloy during solidification

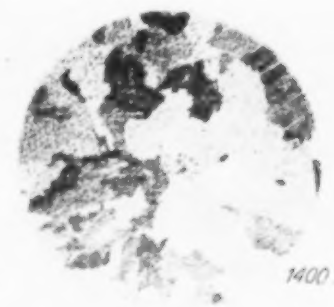
Photographs by Aluminum Company's Research Laboratories.



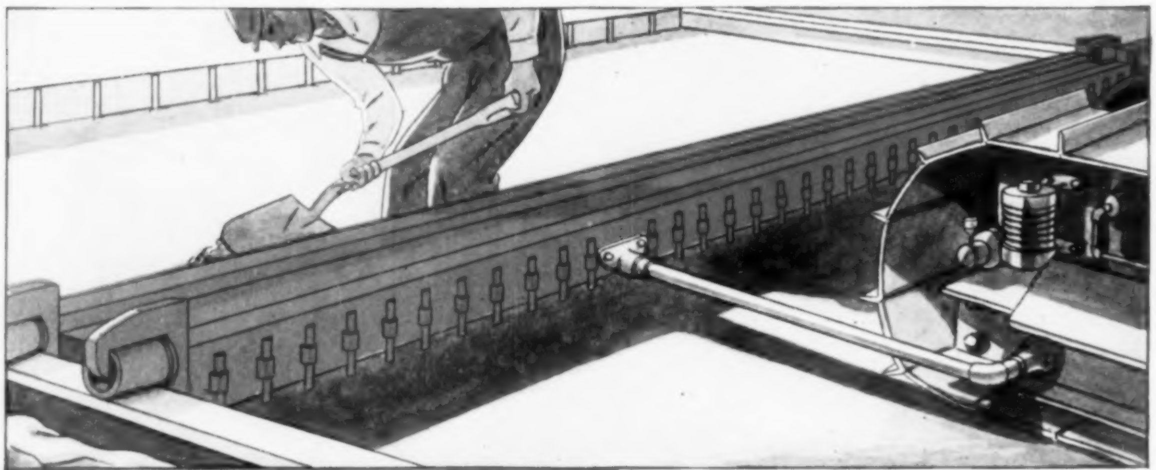




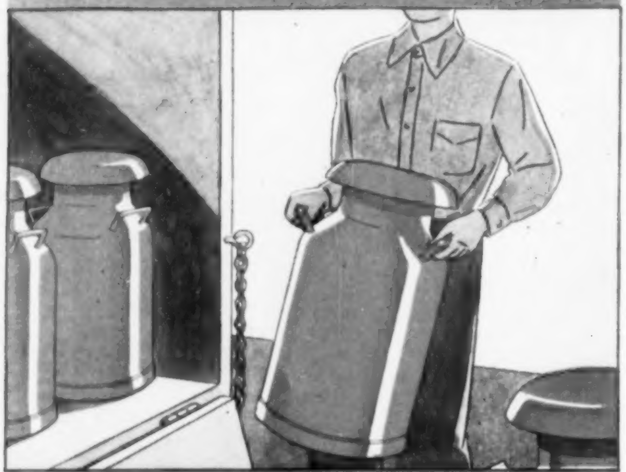




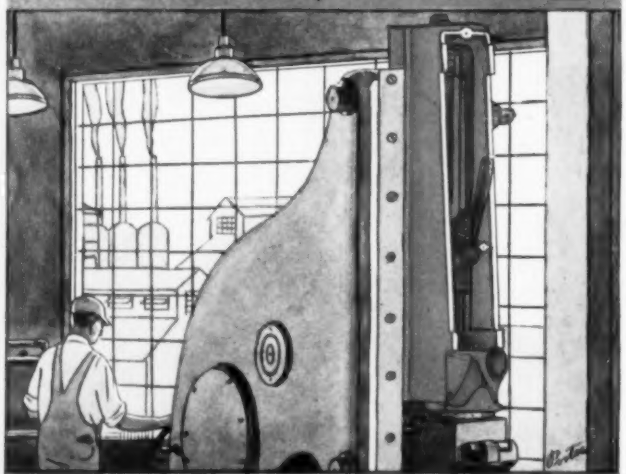
Macrographs, double size, of samples of ¾-in. sand cast bars, show the grain size of the metal when poured at the Fahrenheit temperatures noted. Etched with a solution of 10% HCl, 10% HNO_3 and 5% HF



A scratchboard for testing highways



A milk can for up-to-date dairies



A ram for a machine shop shaper

DIFFERENT

as can be—yet all made of Alcoa Aluminum . . .

The strong alloys of Alcoa Aluminum went to work with a will on these three jobs—Result:

A subgrade highway tester made of Alcoa Aluminum weighs only 93 pounds. It is so light and easy to handle it speeds up handling operations. And it is so accurate that it can save contractors hundreds of dollars a mile. This saving is on the additional concrete usually allowed to cover the errors made by the usual "scratchboards" or testers.

An aluminum 10 gallon milk can that weighs only 18 pounds as against 26 pounds for a can of ordinary construction. And with dairies that handle hundreds of cans that means a daily weight saving that can only be measured in tons. Furthermore, all these cans of aluminum need no inner lining and the yearly expense of retinning is eliminated.

An aluminum ram for a machine shop shaper replaces one made of cast iron. The lighter weight of the aluminum ram permits higher operating speeds, increased efficiency.

The light, strong alloys of Alcoa Aluminum are equivalent in tensile strength to structural steel, yet only 1/3 its weight. They can be readily forged, cast, extruded or machined. Alcoa Aluminum can be welded or put together with aluminum alloy rivets, bolts and screws. And its cost is comparable to that of other metals which do not have its specific advantages.

Large warehouse stocks of Alcoa Aluminum are carried in principal cities. Write for the name of your nearest distributor and a copy of "Alcoa Aluminum and Its Alloys." ALUMINUM COMPANY *of* AMERICA; 2501 Oliver Building, PITTSBURGH, PENNSYLVANIA.

Railroads use Alcoa Aluminum even in the roundhouse . . .

In each of 23 doors of a roundhouse on the Norfolk and Western, there's a weight saving of 757 lbs. because each door is made of Alcoa Aluminum. Furthermore, these doors resist the corrosive action of sulphur-laden smoke. They need no painting. The cost of maintenance is slight.

ALCOA ALUMINUM

Correspondence and foreign letters

TURIN, *Italy* — SOME years ago, the technical advantages of the electric furnaces made it possible to solve many metallurgical problems; the electric furnace could therefore be considered as being responsible for much progress in metal. In recent years, on the other hand, the more important improvements in the construction of electric furnaces have certainly been made to meet the difficult requirements of many of the new metallurgical products.

A typical instance is the rapid development in Europe of the "Ugine-Infra" self-regulating induction furnaces.

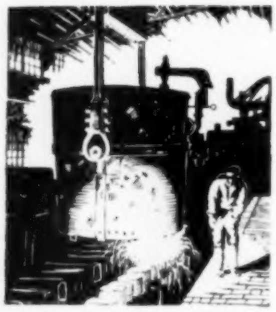
In addition to many conventional processes, such as normalizing or case hardening, which require a given temperature to be kept approximately constant, there are many new operations that are only possible when a temperature (which is often comparatively low) can be maintained constant within very narrow limits for a very long time. Among these last processes may be mentioned the heat treatment of aluminum alloys, the nitriding of steel, the age hardening of titanium steel and titanium-silicon steel.

Formerly, the best results were obtained by using gas or resistance furnaces, equipped with suitable apparatus for automatic control. These devices, though greatly improved during the past few years, are still expensive and complicated. It would appear that the Ugine-Infra furnace offers a simple, reliable, and economical solution of these operating problems.

It will operate on alternating current of any voltage or number of cycles generally available in industry. Its essential part is a muffle made of the proper magnetic ferro-alloy, which not only contains the work but acts as a hollow transformer core. This muffle is placed in the approximately constant magnetic field produced by a surrounding solenoid, through which the regular industrial current circulates. The muffle is also enclosed in a conductive shell of non-magnetic metal, and the magnetic circuit is closed, outside the muffle, by laminated cores. The solenoid is properly insulated against the heat to be developed in the muffle, its contents, and its non-magnetic sheath.

Unique and Automatic Control of Temperature

In operation, the alternating flux passing through the magnetic muffle sets up alternating currents in the conductive shell, whose intensity is a function of the induction of the core. These currents, in addition to the Foucault currents and the hysteresis losses, heat the metallic sheath, and, being well insulated thermally, it transmits practically all its heat inward to the muffle. When this has reached its magnetic



transformation point, its induction (and therefore the heat generated in the non-magnetic shell) decreases suddenly.

From this moment the temperature of the non-magnetic shell or sheath is only influenced by the heat generated by the Foucault currents and by the effect of the hysteresis cycles of the core; if this heat is not sufficient to compensate for the losses from the furnace, its temperature will drop below the magnetic point of the core, and the heating process will begin anew with strong intensity. The result is that the temperature remains practically constant at the magnetic transformation point of the muffle acting as a transformer core.

By proper choice of the alloy used for it (iron-cobalt, iron-nickel, iron-cobalt-nickel, or more complex alloys) the temperature can be fixed at almost any degree between 550 and 2200° F., and by choosing an alloy with good magnetic reversibility, the temperature will automatically remain within 2 or 3° F. Industrial furnaces of this type are extremely simple and strong; the automatic control of the temperature is absolutely reliable, and independent of any external apparatus.

Temperature can be raised without changing the muffle by placing in it pieces of alloys having higher transformation points. Heat can also be maintained automatically at different degrees in different parts by the same methods or by making the muffle of several appropriate magnetic materials.

A number of these furnaces have been now in operation for a long time, giving complete satisfaction, and are consequently increasing in popularity in France and in this country. Very interesting applications have been made in the automatic heat treatment of special steels, where the magnetic changes of the muffle and of the pieces under treatment simultaneously and automatically control the temperature and the movement of the pieces through the furnace, the quenching bath and the drawing or tempering oven.

FEDERICO GIOLITTI

Mechanism of Inverse Segregation

SENDAI, *Japan* — INVERSE segregation is a phenomenon occurring when alloys are cooled rapidly in a chill, in which the component of higher melting point segregates toward the central portion of an ingot, while the more fusible partner component segregates along the outer surface, in contradiction to what would be predicted by the equilibrium diagram. Many explanations have already been proposed by several students of the problem, but no definite conclusion can be derived from them.

Previous experiments were mostly on solid solution alloys with a large solidifying interval. On the other hand, Kei Iokibé recently investigated simple non-ferrous alloys like tin-zinc, whose components do not form solid solutions and yet have fairly large solidifying intervals; since no diffusion is anticipated, it is easier to identify the constituents microscopically than in complex solid solutions.

Segregation was determined by chemical analysis and confirmed by microscopic examination. Densities of the cylindrical specimens of different concentrations were also determined, and for some specimens the changes in density along the length and radius were also studied. Since segregation varies directly with the velocity of cooling, the above determinations were made both for chill cast and sand cast specimens. The principal experimental results obtained by Iokibé are included in the following four items:

1. Inverse segregation is found in chill cast alloys whose component metals form no solid solution with each other. In a sand casting, the segregation is very small. The degree of segregation is proportional to the solidifying interval of the respective ingots.

2. Inverse segregation occurs in the tin-zinc system when dissolved gases are driven off by evacuation during melting and solidification. Segregation is affected little if any by dissolved gases.

3. Density is smallest at the middle portion of the ingots, as well as at the central region of each cross-section along the length. This is due to a lack of mother liquid, as was proved microscopically by noting the existence of many contraction cavities.

4. According to the micro-examination, the amount of primary constituent is less in the more undercooled surface than at the center, this result agreeing with the results of chemical analyses.

From these facts, Iokibé concludes that the phenomenon of inverse segregation is connected with the very rapid freezing, in an undercooled condition, of alloys with fairly large solidifying range, and is caused by a movement of the melt from the center toward the outer portion so as to feed the volume shrinkage (6.5% for zinc) due to the crystallization there of the primary constituent. As the result of this outward shift, the following two circumstances arise which cause inverse segregation in the tin-zinc and similar alloys:

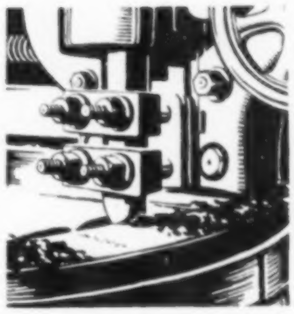
1. After the outermost surface is solidified, volume shrinkage occurs in the next layer (due to the separation of the primary crystals) and in order to fill the vacant space thus produced, the melt inside flows toward the outside. Meanwhile, the liquid interior has also separated some of the primary constituent in itself, and the concentration of the melt thus given to the outer periphery would be richer in tin than the average composition. Accordingly, the more of this volume shrinkage in the outer layer, the greater proportion of the melt will flow outwards and the final consequence will be that the outer crust is formed which is richer in tin than the average composition of the whole mass.

2. In the central region which solidifies last, the primary crystal is first separated and then the eutectic, but owing to the movement of the melt toward the outside, a shortage of the mother liquid causes many minute voids at the boundaries of the primary crystals. In other words, the amount of the eutectic fluid is much less and the amount of primary zinc is normal at the center, when compared with the outer layer and hence the composition would be, on the average, richer in zinc. This enhances the enrichment of tin in the outer layers of the ingot, due to the mechanism described in the paragraph just above.

The same explanation will obviously be applied to segregated alloys forming a solid solution.

Kotaro Honda

To Harden Metal Magnetic Field Must Be Correct



Manchester, *England* — Rotary magnetic treatment was first applied to steel in February, 1929. Since that date innumerable experiments have been made and all kinds of difficulties have been encountered — except one. In no single instance, since I adopted the method of investigation by serial hardness tests, has the magnetic treatment failed to set up hardness fluctuations in the steel. In no single instance were the hardness changes such as could be attributed to experimental error or to local variations.

Against this body of experimental evidence, Mr. Harrington in the last issue of Metal Progress quotes two experiments which were unsuccessful. Unfortunately, he has given no data on the strength of the magnetic field or of the magnetic induction in his specimen.

It seems clear that for a given quality of steel there is a somewhat narrow range of field strength which is effective. A weaker field sets up fluctuations which are quite definite but feeble. Too strong a field, on the other hand, sets up fluctuations of another character and its effect is quite definitely a *softening.*

All my early experimental work was done with a magnet whose strength, by a fortunate coincidence, fell within the critical range. Mr. Harrington has apparently been less fortunate. The pendulum hardness tester may reveal changes of which other instruments would give no indication, but there is evidence that the changes in question are capable of being measured by other hardness testers. The hardness fluctuations in freshly quenched carbon steel and those resulting from rotary magnetic treatment have been investigated and confirmed in England by the use of the Vickers diamond pyramid test.

It becomes increasingly clear that the hardness fluctuation set up by rotary magnetic treatment is not an isolated phenomenon but one which is of very wide occurrence. Similar

periodic fluctuations in duralumin, in freshly quenched steel, or in superhardened steel, induced by thermal, mechanical, and magnetic processes, have been found to be susceptible of magnetic stabilization by the use of the constant field. It is therefore probable that all are essentially similar. Their occurrence has been confirmed by Brinell, Rockwell, and Vickers testers, and the scleroscope.

Finally — this is not a new nostrum for hardening metal, but a newly discovered property of matter. EDWARD G. HERBERT

Makers of Stainless Castings

PHILLIPSBURG, *N. J.* — PERHAPS many readers would be interested in a list of American foundries making corrosion-resistant castings of high chromium alloys. Such a list is given below, together with a letter representing the licensing organization. "A" means American Stainless Steel Co., "C" means Chemical Foundation, and "K" means Krupp Nirosta. I have also indicated the firms using high frequency induction furnaces by an "X," they being five in number. It should be remembered that this list is of licensed castings manufacturers; a few of them also make rolled, drawn, or forged products.

B. F. SHEPHERD

Solubility of Zinc and Aluminum in Magnesium

FREIBERG, *Germany* — IMPORTANCE of "Electron" metals was briefly discussed by Dr. Giolitti in January METAL PROGRESS. In this connection H. Seeliger's work at Freiberg School of Mines should be of interest. He studied the saturation limits of the important solid solutions formed of magnesium and low percentages of zinc and of aluminum (shown at magnified scale at the right of both diagrams herewith).

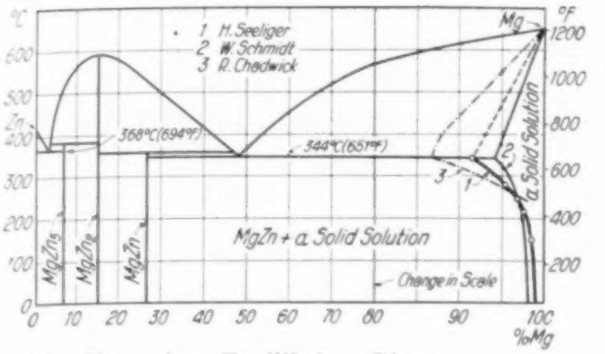
Saturation limits of the alpha and delta solid solutions respectively have been repeatedly investigated metallographically; nevertheless, the curves in the two diagrams are quite different. It is therefore possible that the precipitated particles have not coagulated sufficiently to form grains observable under the microscope.

Now, however, an accurate determination of the lattice constants by means of X-rays permits us to analyze the structure present before the crystallizing particles of excess constituent have reached microscopic size.

For accuracy, suitable reflections should be obtained with the greatest possible angle of deflection. Accordingly, a camera is used in which the film is perpendicular to the incident ray between the X-ray tube and the substance

Foundries Making High Chromium Alloy Castings, Corrosion Resistant

Babcock & Wilcox Tube Co., Beaver Falls, Pa. — C-K-X
Brighton Electric Steel Casting Co., Beaver Falls, Pa. — A
Calorizing Co., Pittsburgh — K
Chapman Valve Mfg. Co., Indian Orchard, Mass. — A-K
Chrome Alloy Products, Inc., Nicetown, Pa. — A-K
Cooper Alloy Foundry Co., Elizabeth, N. J. — A-C-K
Crucible Steel Castings Co., Cleveland — C
Driver Harris Co., Newark, N. J. — C-K
Duraloy Co., Pittsburgh — A-C
Duriron Co., Dayton, Ohio — K-X
Electric Steel Foundry, Portland, Ore. — K
Empire Steel Casting Co., Reading, Pa. — A
Enterprise Foundry Co., San Francisco — C
Forging & Casting Co., Detroit — C
General Alloys Co., Boston — C-K
General Metals Corp., San Francisco — K
Hartford Electric Steel Co., Hartford, Conn. — A
Ingersoll Steel & Disc Co., New Castle, Ind. — C
Interstate Foundry & Machine Co., Johnson City, Tenn. — K
Lebanon Steel Foundry, Lebanon, Pa. — A-C-X
Michiana Products Corp., Michigan City, Ind. — A-C-K
Michigan Steel Casting Co., Detroit — C
Midvale Co., Philadelphia — A-C-X
Millbury Steel Foundry Co., Millbury, Mass. — K
Milwaukee Steel Foundry Co., Milwaukee — C-K
Monarch Foundry & Engineering Corp., Stockton, Calif. — C-K
Ohio Steel Foundry Co., Lima, Ohio — C
Pacific Car & Foundry Co., Seattle, Wash. — K
Pacific Foundry Co., San Francisco — K
Riverton Steel Co., Pittsburgh — C
Shawinigan Stainless Steel & Alloys, Shawinigan Falls, Que. — K
Sivyer Steel Casting Co., Milwaukee — A-C
Standard Alloy Co., Cleveland — K
St. Joseph Electric Steel Casting Co., St. Joseph, Mich. — K
Symington Co., Rochester, N. Y. — C-K
Taylor Wharton Iron & Steel Co., High Bridge, N. J. — C-K-X
Texas Electric Steel Casting Co., Houston, Tex. — K
Union Electric Steel Corp., Pittsburgh — A-C
Union Spring & Mfg. Co., New Kensington, Pa. — A
Warman Steel Casting Co., Ltd., Los Angeles — K
Wehr Steel Co., Milwaukee — A
West Steel Casting Co., Cleveland — C-K

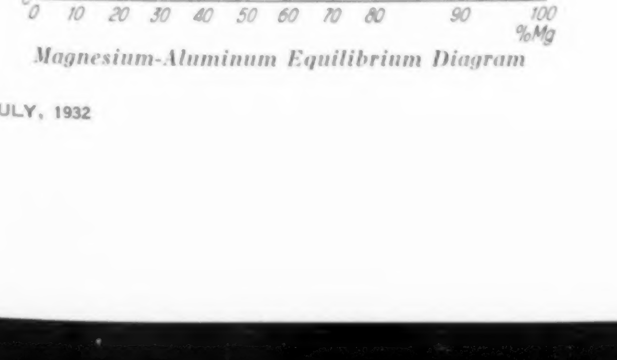


Zinc-Magnesium Equilibrium Diagram

being analyzed, and so placed that only rays reflected at a wide angle reach the film.

Computation of the concentration limits at different temperatures should naturally be based upon a knowledge of the general structural changes of the solid solutions up to the highest possible contents of zinc and aluminum. Since solid solutions have the highest possible alloy concentrations at the eutectic temperature, as is apparent in the diagrams, samples of compositions with varying zinc (or aluminum) content were melted at the eutectic temperature, held at 651° F. and 817° F. respectively, quenched from this temperature in water, and the structure observed.

For quantitative determination Seeliger used the Debye-Scherrer ring of reflections made by the $K\alpha_1$ radiation from the crystal planes (1,0,-1,5) and (1,1,-2,4) and by the $K\beta$ radiation of iron from (2,1,-3,3) planes. Lattice dimensions (lengths of the upper edge c and the lower edge a of the six-sided elementary prism, ascertained by solution of the Bragg reflection equation) show a linear decrease from pure magnesium with increasing additions of zinc and aluminum respectively, up to about 3.28 atoms per cent zinc (8.47% by weight) and 11.0 atoms per cent aluminum (12.1% by weight) — these concentrations corresponding to the beginning of the eutectic range — after which they are unchanged. The lattice contracts with increasing alloy content, this contraction being more marked for zinc than for aluminum.



Magnesium-Aluminum Equilibrium Diagram

These straight line relationships between lattice size and crystal parameters are fixed by the following points. Intermediate determinations, when plotted, fall very close to the line.

LATTICE DIMENSIONS IN ANGSTROM UNITS

	a	c
Mg	3.20	5.20
Mg + 3 atoms % Zn	3.189	5.179
Mg + 11 atoms % Al	3.158	5.146

In order to determine the solid solubility line, good homogeneous samples, supersaturated with zinc and aluminum respectively, were heated a sufficient time at various constant temperatures from 300° to 750° F. to precipitate the surplus zinc or aluminum. By quenching in water these conditions can be fixed at room temperature.

After ascertaining the lattice constants of samples so treated, the concentrations of the various solid solutions can be taken directly from the information on solid solutions derived at the outset. The results are shown in the equilibrium diagrams as small circles. The exact form of the curve is given in the following table:

Temperature		Saturation Concentration Per Cent by Weight	
°C.	°F.	Zinc	Aluminum
150	302	1.71	2.60
200	392	2.00	3.20
250	482	3.29	4.10
300	572	6.00	5.30
344	651	8.41	–
350	662	–	7.32
400	752	–	10.66
436	817	–	12.10

The probable course of the solidus line at higher temperatures is indicated by a broken line. From the position of the curve at lower temperatures a solubility at room temperature of about 1% zinc and 2% aluminum is found; the latter is considerably lower than the value formerly accepted.

Ed. Maurer
W. Bischof

Endurance of Steel With a Nitrided Case

London, *England* — Nitride hardening has received a great deal of discussion in technical literature in recent times both in America and in this country, but it seems that there is still much to be discovered concerning the process and its mode of action. Use of nitride hardened steel is spreading somewhat slowly in this country, partly, no doubt, because of existing industrial conditions and partly also because confidence in the product is not yet completely established. There is no doubt as to the hardness and wear-resisting qualities of the surfaces when prepared on suitable steels. Misgivings arise, however, in regard to the brittleness of the coatings.

It has been suggested that a development of the process which would produce a tougher surface layer, even if the hardness were diminished considerably, would constitute a valuable advance and there is some hope that this may be achieved. It is also hoped that the limitation which requires the use of a special alloy steel containing aluminum may be overcome.

At the recent meeting of the Iron & Steel Institute in London Dr. Fry of Messrs. Krupp, who is the originator, presented a very interesting paper on the nitride hardening process. It is possible to touch here upon two of the points which he raised.

One of these is the question of how the extreme hardness of the surface layer is produced. Dr. Fry definitely ascribes it to a precipitation process of the same nature as that which occurs in the well-known phenomena of age hardening. His view appeared to be that the formation of the nitride (especially aluminum nitride) causes a severe disturbance of the space lattice of the ferrite in which it is embedded, and this disturbance becomes so severe that the iron is raised to the maximum possible degree of hardness of which it is capable, considerably exceeding the hardness of martensite. In accordance with this view is the fact that martensite itself is capable of further hardening by cold work, which is believed to increase the lattice distortion of the alpha iron present in the martensite. On the other hand, the evidence available to prove Dr. Fry's theory of nitride hardening appears to be scanty.

We should expect to find that X-ray spectra taken from the surface layers of nitrided steel would show extremely diffused lines owing to the supposed violent distortion of the lattice; yet Dr. Fry himself reported in his paper results of X-ray examination by other workers in which there were no indications of serious lattice distortion. It is, of course, possible that what we understand by "lattice distortion" need not necessarily imply a geometrical disarrangement of the atoms on the lattice, but may consist in such a disturbance of the electrons (supposedly holding the atoms together) that the normal processes of slip are hindered or prevented. A disturbance of this kind might occur without seriously affecting the X-ray spectrum. There is reason to believe that under certain conditions the age hardening of aluminum alloys may occur in some such manner, since cases have recently been discovered in which an age hardened aluminum alloy shows little distortion of the lattice as determined by X-rays.

On the other hand, it is possible that the true explanation of nitride hardening is dependent upon the formation of crystals (which may be extremely minute) of a hard body such as iron nitride. At first sight this problem appears to be of purely academic interest, but if we are to control the nitriding process so as to obtain less brittle coatings, a knowledge of the mechanism is of first-rate importance.

The second point in Dr. Fry's paper relates to fatigue resistance. Tested by the Wöhler or alternate bending method the nitride hardened steel shows improved endurance as compared with the same steel in the untreated condition. The same applies to a slightly lesser extent to ordinary case hardened or carburized steel. This is to be expected from the fact that under bending action the most severe stresses are developed in the outer skin; hardening of this outer skin will bring with it improved resistance. It was pointed out in the discussion, however, that this improved resistance could not be expected and was, in fact, not realized

when the nitride hardened steel was subjected to direct push-and-pull stresses (such as occur, for example, in the piston rod of a Diesel engine, to which Dr. Fry had specifically referred).

Nitride hardened steel, however, retains even under these conditions the great advantage that it is more resistant to corrosion fatigue than untreated steel. Since corrosion fatigue is apt to occur where it would scarcely be looked for, this advantage is important and may give a field of usefulness to nitride hardened steel which is independent of the actual high surface hardness. This also raises the question whether it is not possible to increase the corrosion fatigue of steel surfaces by other forms of treatment, such as cementation with other elements, which might avoid some of the disadvantages attaching to the nitriding process.

WALTER ROSENHAIN

Methods of Determining Effects of Corrosion

PARIS, *France* — MOST of the numberless publications on corrosion measure its results by loss of weight. A heedless generalization of such a method must be avoided, though it obviously is the simplest and easiest. For instance, it cannot be employed to determine degree of tarnish on chemical resistant alloys, and it has the added disadvantage of interrupting the reactions, which may deeply disturb the progress of the phenomenon.

As an example, the writer, jointly with M. Sanfourche, recently showed that an 18-8 stainless steel, corroded in phosphoric acid solution containing a small quantity of hydrochloric acid, became passive for several hours after interrupting the corrosion to make a weighing, and it was consequently impossible to plot a time-corrosion curve by such means.

What is to be emphasized is this: That the methods of appraising the damage done by corrosion must essentially depend upon the nature of the chemical or physical actions involved. Five principal modes may be singled out; they are:

1. *Uniform solution.* The metal is reduced in thickness the same all over as when copper is dissolved in nitric acid, or magnesium in citric acid. In such cases it is logical to measure the effect by the loss of weight or, better, the depth of corrosion.

2. *Localized corrosion in pits or seams.* The surface is studded with indentations and becomes at length quite wrinkled or pock-marked. The effect on the mechanical properties is not proportional to loss in weight, since the pits act as notches and considerably reduce the capacity for deformation and consequently the elongation and contraction of area in a tension test. This kind of corrosion is a statistical phenomenon. For the same loss in weight a tank sheet may undergo a negligible superficial thinning when the corrosion belongs to class 1, or be useless owing to perforation when the corrosion belongs to class 2. Other instances of this second kind of corrosion are aluminum and duralumin exposed to salt water.

3. *Subsurface corrosion.* This develops in depth and provokes either flaws or the chemical transformation of a constituent. The typical case is "graphitization" of cast iron in sea water which in time transforms it into a product having no cohesion, when its appearance, even the tool marks, remains unaltered. Variation in weight is evidently of no use to measure this phenomenon.

4. *Corrosion cracking.* Under the influence of particular reagents, some metals and alloys spontaneously crack, and the cracks are propagated between the crystalline grains. The metal has lost its resistance and there exists no relation between the loss in weight and the amount of the deterioration. The classical case is cold worked brass which cracks when exposed to mercury salts or sundry products containing ammonia. Other examples are cold worked aluminum in sea water and the intercrystalline corrosion of chromium-nickel stainless austenitic steels, quenched and tempered and immersed in acid solutions of copper and iron sulphate. For a precise example: A 2-mm. sheet of steel containing 18% Cr, 7.6% Ni, 0.13% C, exposed to the above conditions was altered to

such a degree as to break immediately when attempting to bend it; the sheet had become friable and was consequently of no use, though its loss in weight corresponded to a thickness reduction of 0.05 mm., an amount which should have no measurable effect on the mechanical properties if it had been uniformly dissolved. Such alteration is not easily detected even when the surface has been polished to a mirror; a measurement taken with a photo-electric cell showed a loss of 21% in the reflective power; if the surface had previously been sanded, nothing could be seen. The most effectual mode of testing after such corrosion is the qualitative one of striking the piece and listening to the note it gives forth; an unattacked sheet is sonorous, whereas an attacked sheet gives a sound as hollow as would lead.

5. *Specific brittleness caused by corrosion.* Sometimes some specific property of the metal may be altered by an external chemical influence without any loss in weight. Examples are the brittleness of mild steel induced by chemical influences which evolve atomic hydrogen when brought into contact with it. Here, also, the loss in weight has no significance.

Thus, among the above five kinds of corrosion, the first alone may be appraised by measuring the loss in weight, and it is far from being an every-day occurrence. The problem may be solved better by comparing the alteration of some judiciously chosen physical property (which depends on the case investigated and may be loss in weight, brilliancy, or sonority) and the corresponding change in a given mechanical property, such as expansion, tensile strength or hardness. Finally, this must be correlated with the results of experience.

Albert Portevin

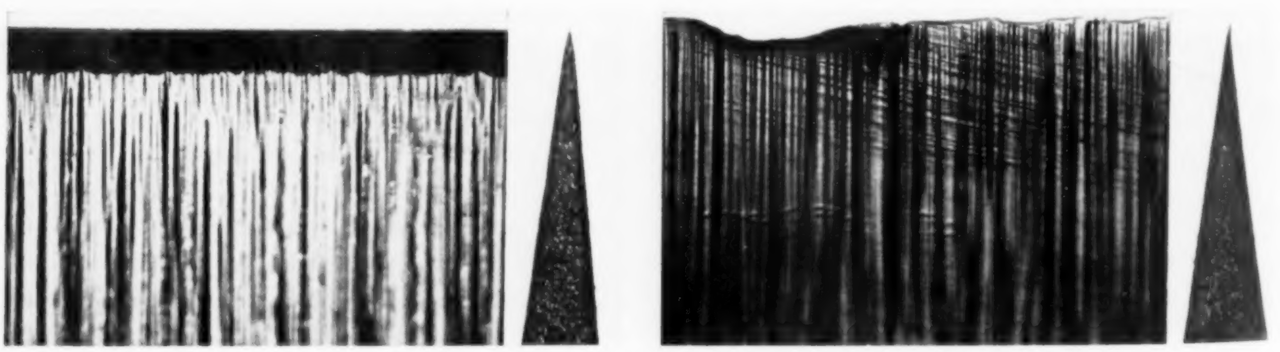
Edges of Good and Bad Razors

Hartford, *Conn.* — Those who read the editorial comment on razor blades in the April issue may be interested in these photos, at 100 magnifications, showing the characteristics of some razor edges met daily on the market. One pair shows the edge as normally viewed, and in cross-section, respectively, of a blade from a lot which performed satisfactorily. Similar views of another blade from a lot which gave relatively poor results show an uneven and hooked edge. It is obvious why one blade is better than the other.

Such things as the quality of the steel, hardness, microstructure, perfection of the edge, angle of edge, and thickness of stock, all influence the "shavability" of a blade. The variation in quality, blade to blade, even in the same package, indicates the difficulties encountered in controlling all these factors simultaneously, in production routine.

With regard to magnetic sharpening: The writer has been unable to discern any improvement in blades so treated. Prof. McKeehan also reports in *Physics* (December, 1931) no definite evidence of magnetic sharpening in tests which he made. However, the improvement ascribed to the use of the magnet is probably real when it causes the user to clean and dry his blade more carefully after each shave. Care in this respect usually leads to more satisfactory shavability and longer life of the blade. In fact, the satisfaction afforded by some of the alloy blades appears to be due largely to their corrosion resistance, which practically eliminates deterioration of the edge from lack of careful cleaning.

James J. Curran

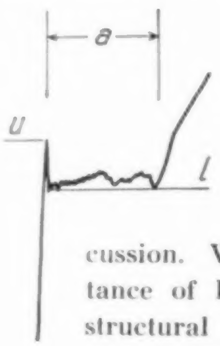


Condition of Edges (Viewed at 100 Magnifications) of Commercial Safety Razor Blades

Yield Point Included in New Swedish Specifications

Stockholm, *Sweden* — A Government committee recently proposed to insert provisions concerning the yield point in standard specifications for structural steel for buildings and bridges to be used among others by the Swedish State railways. It preferred the "lower yield point" to the "upper yield point," as the lower is generally supposed to give a more correct indication of an inherent property of the material.

In Sweden (as in America) we generally define the yield point as the unit load where a marked stretch occurs without any increase in the stress required to produce it. This definition, however, does not tell the whole story, as seen from an accurate stress-strain curve for a mild carbon structural steel. Load *u* marks the upper yield point and *l* the lower yield point; the distance *a* may be called the yield range.



This proposal to specify lower yield point has caused a good deal of discussion. While the fundamental importance of knowing the yield point for structural steel was recognized, doubts were expressed as to the advisability of stipulating definite requirements at the present moment. It was only recently that it was proven, by the use of autographic testing machines, that the lower yield point is a characteristic property of the material. Furthermore, its relationship to different manufacturing operations and to the conditions under which the test is carried out, was not sufficiently well understood to warrant including it into acceptable standard specifications.

The research council of Jernkontoret therefore decided to place funds at the disposal of Axel R. Lundgren of the Swedish Government Testing Institute to investigate the yield point of structural steel. Steels studied by him were delivered by three mills, taken from seven different heats. Two groups of standard structural steel were represented, namely, St 37 and St 44 with tensile strengths 37 to 45 and 44 to 52 kg. per sq.mm. respectively (53,000 to 64,000 and 63,000 to 74,000 lb. per sq.in. respectively). Four of the materials were rolled into shapes ranging in size from 3/8-in. round to 1x5-in. flats, and three of the heats were rolled into plates from 3/8 to 1 in. thick. Typical analyses are given in the table.

	C	Mn	Si	P	S
St 37, killed	0.10	0.33	0.15	0.032	0.036
St 37, non-killed	0.17	0.58	0.02	0.032	0.035
St 44, killed	0.27	0.52	0.18	0.042	0.046
St 44, non-killed	0.27	0.50	0.01	0.029	0.038

Test bars of several dimensions were employed and several rates of extension were tried. A detailed account of the results is given in Jernkontorets *Annaler*, October, 1931.

Lundgren studied in detail the yield range of the stress-strain curve. The appearance of this range varies widely; ten different types of diagram were observed. In plate materials the upper and lower yield points were quite close together. Round test bars often gave very irregular diagrams, difficult to interpret. Otherwise, no marked relation was found between the form of the test bar or the quality of the material and the type of diagram obtained.

When the testing speed was not too high, corresponding to an increase of stress smaller than 40,000 lb. per sq.in. per min., a good agreement was found in the values obtained for one and the same material, irrespective of the dimension of test bar used. According to Lundgren the probable accuracy of a single test made at moderate speed is as follows:

Upper yield point,	3,000 lb. per sq.in.
Lower yield point,	1,800 lb. per sq.in.
Tensile strength,	1,400 lb. per sq.in.

The relation between yield point and tensile strength was found to vary within fairly wide limits. Most of the tests, however, passed the proposed requirements of a minimum lower yield point of 31,500 lb. per sq.in. for the 60,000-lb. steel and 37,000 lb. per sq.in. for the 70,000-lb. steel. On the basis of Lundgren's investigation Jernkontoret also recommended that the allowable spread be increased from the originally proposed 3% to ±5%, and this recommendation was adopted.

This is probably the first time that yield point has been specified in standard specifications for structural steel.

Einar Öhman

By Hans H. Diergarten
Schweinfurt, Germany

German ship builders use arc welding extensively

SHIP WELDING, as developed during the last few years, has become a most interesting chapter in the history of German shipbuilding and metallurgy. The great impetus is probably due to the needs of our navy, for, according to Capt. Hermann Lott, twelve destroyers and three cruisers (including the Ersatz Preussen launched last spring) have successively used an increasing amount until finally the entire ship was welded with the exception of a few parts. As many as 100 gas welders and cutters and 200 arc welders were employed on this work. The cost of welded ships was about 3% lower than that of riveted construction, but the prime saving was 12 to 17% of the weight.

In Germany the first ship welding was done on war vessels, and this innovation was due to the Versailles Treaty which sharply limited the size of the combat units and which therefore compelled designers to obtain the maximum performance from small ships. The results have been so satisfactory that the merchant fleet is beginning to use this method of construction. The German Lloyd and British Lloyd have both published general specifications for the use of electric welding in ship construction, and vessels built to conform to these rules are given the highest registration. It is unlikely that the new process will ever be abandoned. The latest cruiser particularly shows its great advantages.

While the Deutsche Werke Kiel is probably foremost in the study and practice of ship welding, other firms such as Blohm & Voss, Deschimag (a merger of five yards) and the government yard at Wilhelmshafen have also promoted the idea vigorously. In a paper entitled "Electric Welding in the Construction of Sea-Going Vessels," read in Glasgow at the February 1931 meeting of the Institution of Engineers and Shipbuilders in Scotland, G. Wahl of the first-mentioned firm reported the following achievements since 1925:

In 1927 a 55-ft. motorboat was built for the company's use (completely welded).

1926 to 1929 witnessed the construction of the cruiser Karlsruhe for the German navy, partly welded.

At the same time two naval tankers were completely welded. These were motor-driven sea-going vessels, about 130 ft. long with 27-ft. beam. Six tanks were amidships with a capacity of about 900 short tons.

In 1930 an ice-breaking car-ferry was partly welded. It was 310 ft. long, 50-ft. beam.

The armored ship Deutschland was launched in 1931. It was only partly welded.

but by this means such good advantage was taken of the permissible weight that foreign observers had much to say about this "pocket battleship."

In 1930 and 1931 the tankers Vardaas and Fjordaas were built under the rules of Lloyd's Register of Shipping. Tank hatchways, auxiliary engine and machine foundations, gangways, cabins, and similar structural parts were electric welded. These ships had a tonnage of 13,000 and 12,000 respectively.

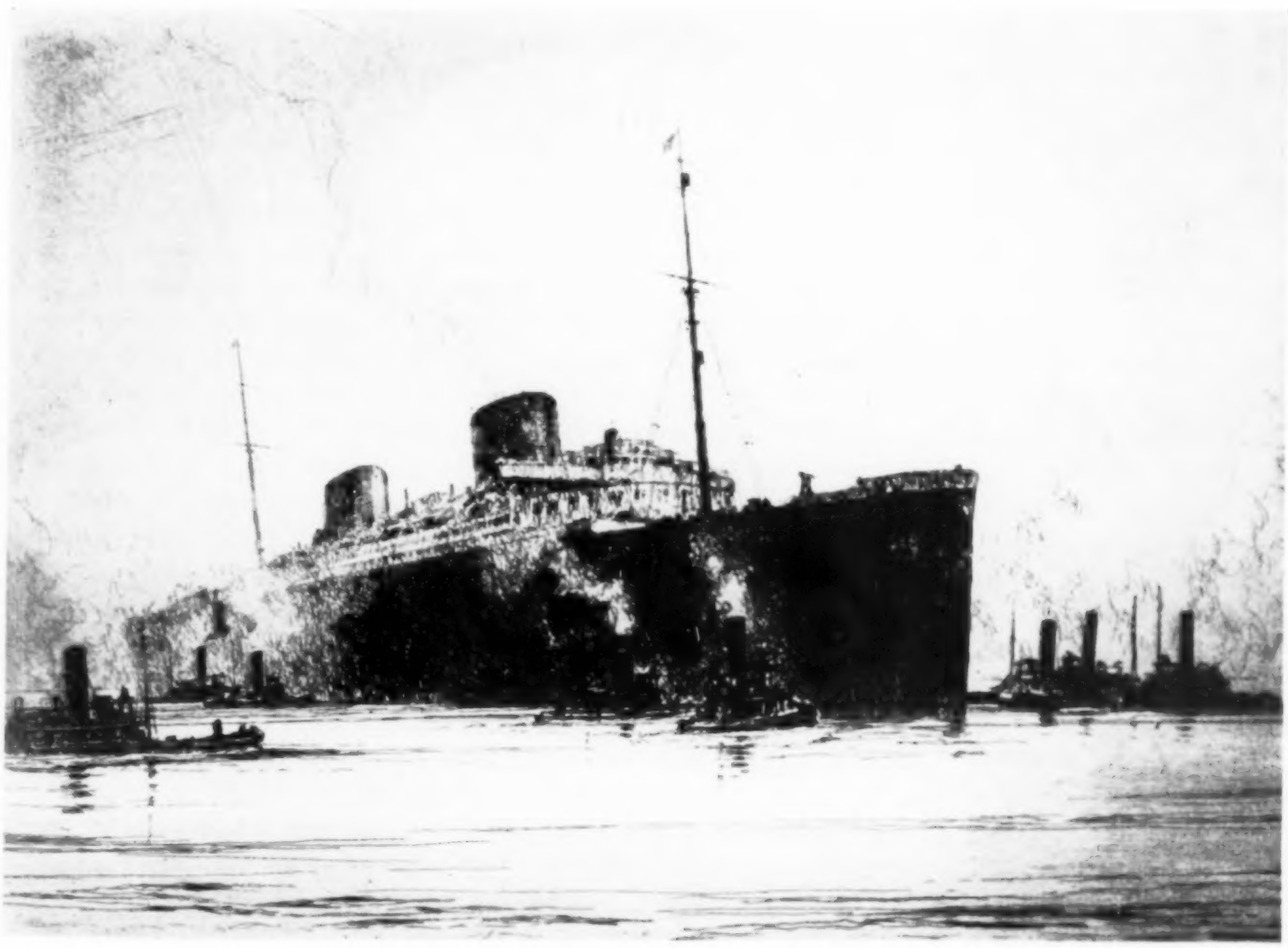
The cruiser Ersatz Preussen was launched in May, 1931.

Besides the above-mentioned ships electric welding has recently been used in a large amount of repair and reconstruction work, particularly on barges.

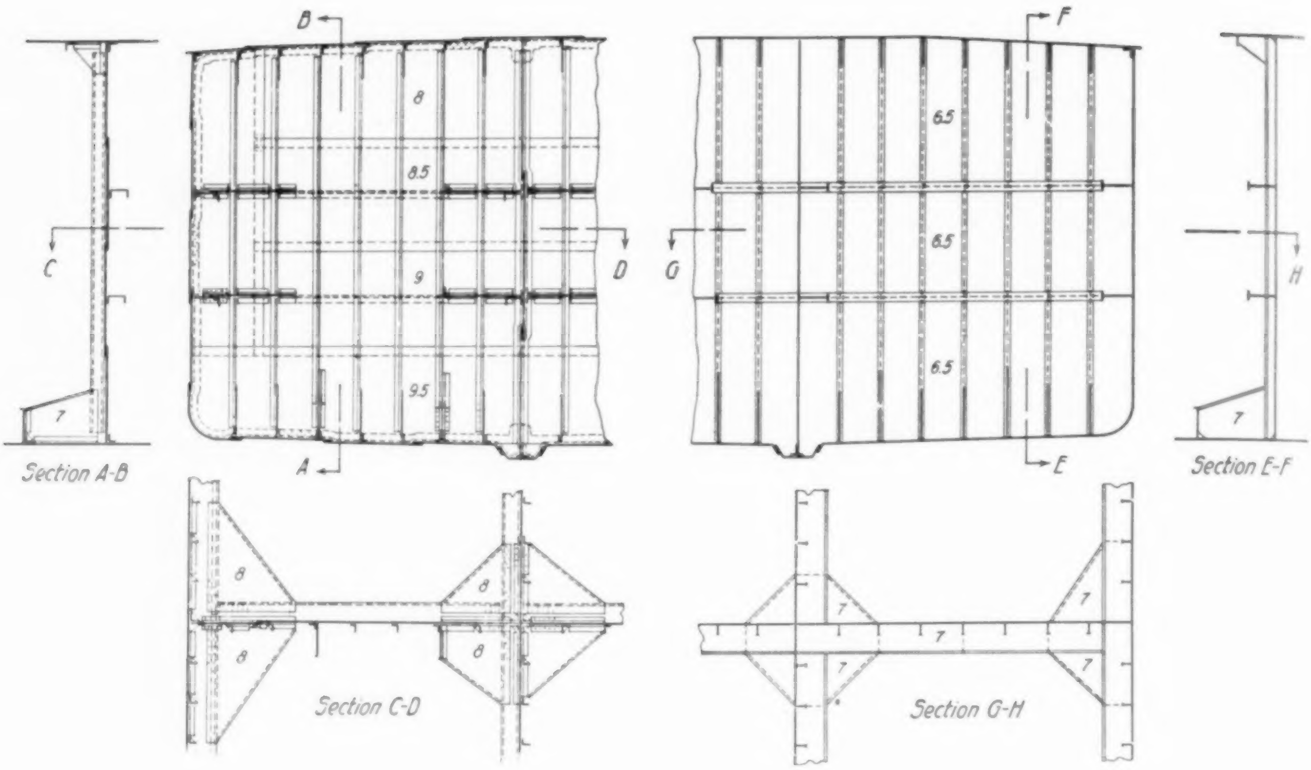
Deutsche Werke Kiel owns about 75 portable and 20 stationary arc welding machines. As many as 130 trained men were employed at the peak of construction; at present there are still 50 welders engaged. When feasible each is allotted his own welding machine which he keeps as long as he is employed. In this way the welder is responsible for his own equipment, and one cause of uncertainty in the results is definitely eliminated.

Welders trained in the years 1925 to 1928 were taken from other trades, such as blacksmiths, foundrymen, machinists, and shipwrights. A special training program lasted 8 or 10 weeks and ended with a regulation examination. The men so trained were next employed on minor fittings in the shop, and after further practice in overhead welding and welding of vertical seams, were assigned to work on the hulls.

In the construction of the two naval oil tankers the thickness of the plating was reduced below that required for riveting, and many details and connecting angles were eliminated, as may be seen in the comparative designs (reproduced from an article in *Werft Reederei Hafen* by Naval Architect Malisius). Since a welded butt joint is at least equal to the strength of the plate itself, one might theoretically decrease the



From an Etching by Otto Kuhler



General Drawing of a Transverse Bulkhead for a Tanker of 27-Ft. Beam. Riveted design at left requires many details at connections which are avoided in welded construction. Thickness of plates in mm.

thickness of the plate to a figure which corresponds to the strength of the plate weakened by rivet holes. This reduction due to rivet holes is about one-quarter the original thickness. In order to withstand impacts when docking and for other reasons, however, the thickness of the plate is reduced only about 1 mm. — say from 8 to 7 mm. (0.31 to 0.28 in.). All parts of the oil tankers were joined by electric welding, and riveting was used only to join the shell plating and the center bulkheads to the keel, and the shell plating to the deck.

Such welding was authorized on the basis of experience gained at Deutsche Werke Kiel that joints made with a standard electrode possess the same strength as ship steel, although tension test pieces cut from a block of weld metal showed a lower elongation.

It should be noted that welded ships have the advantage of being less sensitive to vibration than riveted ships. This is explained by the fact that a welded ship is a single unit and acts as such. This principle of continuity of metal at joints has also been used to advantage in the construction of bridges and large buildings.

The decisive factor in the introduction of welding to ship construction is a comparison of cost and weight. Engineers for the Deutsche Werke Kiel computed accurately the weight of the welded design for the two oil tankers and compared them to a riveted one of the same size, as given in the German Lloyd tables.

A representative set of results follows. The total weight of steel for the hull, without equipment, was 233 short tons for the riveted vessel, and 160 tons for the welded one. The saving in weight was therefore 73 tons or 32% of the weight of the riveted ship. Four tons more is saved in the fittings, so that the welded oil tanker is about 77 short tons lighter than the riveted tanker. If some additional cast iron equipment were to be made of welded steel, a still further saving would be made.

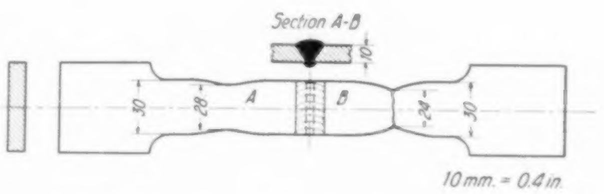
The above-mentioned tanker will carry 660 short tons of oil with permissible freeboard. The riveted one of the same over-all dimensions, which is 77 tons heavier, thus has a capacity of only 583 tons. If, in order to arrive at a correct comparison, a riveted ship with a capacity of 660 tons is designed, it must be 9 ft. longer, and this increase in length corresponds

to 22 tons dead weight. The riveted vessel with 660 tons carrying capacity thus has about 90 tons more displacement than a welded ship of the same cargo capacity. Figuring the cost for these ships of the same cargo capacity, it is found that a welded ship can be built today cheaper than a riveted one, and past experience indicates that the favorable ratio of cost of welded to riveted ships will increase.

Before any ship welding was undertaken by Deutsche Werke Kiel many laboratory tests were made. G. Wahl has described the test pieces in *Die Schmelzschweissung.*

When the weld is at right angles to the axis of the specimen, the plate material necks down on either side and breaks, as illustrated.

If the weld itself constitutes the axis of the test piece, the specimen may be said to consist of three parts, two strips of ship plate being joined longitudinally to either edge of a third strip of weld metal. In such a piece the first fracture occurs in the center bar of weld metal. As the load is increased this hole enlarges with



Butt Welded Test Piece Breaks in the Plate Because the Weld is Stiffer and Stronger

increased reduction of area of the outer strips of more ductile ship plate until they break.

This he explains as follows:

"Since the elastic limit of the outer strips of steel (31,000 to 38,000 lb. per sq.in.) is lower than that of the center strip of stiffer weld material (41,000 lb. per sq.in.) the edges start to elongate rapidly before the center bar of weld material passes its yield point. Therefore, as the load increases, the weld metal carries more than its share of the load. The general extension at the necking-down portion soon surpasses the maximum elongation of the weld material (normally 5%) and it breaks. After this occurs the greater ductility of the ship steel (normal elongation 20%) causes the outer strips of steel to elongate further before they break, thus opening the holes in the joint."

The position of the weld in the first-described test is the same as at the abutting ends of a sheet; it follows that:

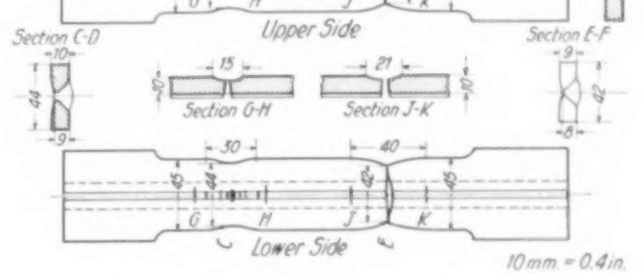
"A weld transverse to the direction of pull has at least 100% the strength of the cross-section of the plate. The butt of the outer shell can therefore lie at the centerline of a main frame. This location has the further advantage of protecting the weld by a reinforcing strap inside the butt joint."

From tests on longitudinal welds as described in the second test piece, it was decided that welds running lengthwise of the ship must be avoided in highly stressed parts; they are permissible only in parts subjected to moderate strain. Where highly stressed longitudinal joints are unavoidable, then ordinary riveting should be used.

After considering the problem from various aspects, it was decided that only butt welds need be used, thus eliminating laps, joggled joints, and scarfing. The two latter are especially expensive. The first experimental motorboat was built in this manner in 1927.

One important point is to reduce the contraction strains to a minimum. Direct current arcs seemed to give a more reliable joint than alternating current and equipment of this sort was obtained from five firms. After the welders became familiar with these machines, they succeeded in reducing the strain on seams to a minimum.

Procedure now is as follows: The workmen tack-weld the assembly of plates at several points. Each seam is then welded, beginning at the center of the joint. If severe strains occur the tacked points will tear apart; weld-



When Test Piece Has a Weld Down Its Axis First Fracture is in the Weld, Because Elongation of More Ductile Edges Throws Excess Load on Central Strip

ing of the adjusted seam can then be finished so the whole section will be free from excessive strain. Plates are originally laid together with a space between about the thickness of the welding wire. The tacked places are spaced about 3½ in. apart.

When erecting a hull the bottom plates are first laid on the empty scaffold and tacked at the required distance. Many parts, such as frames, girders, and bulkheads, which were fabricated in the shop, are then taken to the ways and welded together. Lastly follows the welding of seams and butts in the outer shell. When all the welding is completed, the riveted joints are driven.

Courtesy Allis-Chalmers Mfg. Co.

Especial consideration has been given to the selection of electrodes. It had first to be decided whether it was better to use bare or dipped welding wire or coated electrodes. The last mentioned are expensive and fragile, and require a special technique, and were therefore eliminated from consideration. It seemed that either bare or dipped wire would give satisfactory results in the hand of an experienced and careful worker.

The welders trained at the Kiel shipyards have become most familiar with dipped electrodes. These have a very thin coating, less than 0.01 in. thick; the dipping can be done at a cost of about 1¢ per lb. Since, however, the dipped electrode gives a reliable joint, and since contamination of the weld by nitrogen and oxygen is largely avoided, the Deutsche Werke Kiel now uses them exclusively. On the other hand, the Wilhelmshafen navy yard has continued with bare wire.

When plate of higher strength than the standard ship steel is to be welded (such as the 80,000-lb. steel used for battleships) the standard dipped electrode is unsatisfactory and a special coated electrode must be used. However, since the coating usually introduces slight irregularities into the joint, it is avoided wherever possible. A special dipped electrode has been used which will form an alloy steel joint giving the necessary tensile strength.

Methods used for testing the completed work are particularly noteworthy. Six different methods of inspection have so far been devised. The first and simplest is the examination, during and after welding, by an inspecting engineer. This requires, of course, seasoned experience and special knowledge of welding procedure and the outer appearance of a sound weld.

The second test is the water pressure test. It is used frequently for battleships. It is applied to merchant ships only in certain special cases. If a leak is revealed, this part of the seam should be removed and rewelded, even if it seems permissible to peen or calk it.

Third is X-ray examination, which is seldom used and then only when the weld is easily accessible.

Fourth are some newly developed electrical methods which are similar in principle to Sperry's methods of rail testing.

Sometimes the joint is ground flat at various spots and the quality judged by the structure revealed. This is rather impractical, since individual bad spots are hard to find.

Small launches or boats weighing less than the capacity of floating cranes can be dropped several feet into water when they are launched. If a ship resists this test, it is considered to have excellent strength. However, it is impracticable for large craft.

German engineers place most reliance in the careful examination of the weld by an experienced engineer and the pressure test (air, water, or gasoline). Good design, careful workmanship and adequate supervision inspire confidence in the final result.

Since the development of electric welding in shipbuilding in the last few years has been extraordinary, it can safely be predicted that welded ships will completely supplant riveted ones, and that it will be possible to surmount the difficulties now encountered in longitudinal seams. Welding of the entire ship will then be the rule.

IF THERE WERE ONLY TWO TELEPHONES IN YOUR TOWN

IF THERE were only two telephones in your town the fortunate possessors would probably put them on pedestals in the most prominent places in their homes. Neighbors would flock to see them. Children would clamor to touch them. Bolder ones would lift the receiver to hear the magic voice—then hang up suddenly in bewilderment.

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At any hour of the day or night you can talk to almost anybody, anywhere—to far countries and to ships at sea. The first wonder is that you can talk to folks around the corner. The second wonder is that the service is so organized that you can talk to people in far away lands. The third wonder—perhaps the greatest of all—is that telephone service is so inexpensive.

Of all things purchased, there is none that costs so little and brings to you so much convenience, so much security and achievement as the telephone.

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REPORT of the National Physical Laboratory for 1931 has been published by H. M. Stationery Office, London, England, at 15 shillings. Metallurgical researches there have been directed 25 years by Dr. WALTER ROSENHAIN; he resigned about a year ago to act as consultant, and was succeeded by Dr. CECIL H. DESCH. Work in metallurgy is intimately intertwined with that of the other five departments. As an instance, the Engineering Department is also interested in the fact that the fatigue properties of alloy spring steels are cut nearly in half if the surface is decarburized during fabrication, forging, or heat treatment. This is prevented if the machined surface is covered with powdered graphite or the heating is done in salt baths containing about 25% sodium cyanide. A second joint project has been the study of strong alloys for service between 1100 and 2000° F. It would appear that the most suitable alloy is one which rapidly hardens at the working temperature but then maintains this Brinell hardness continuously. The best alloy so far found contains 30% Ni, 30% Cr, 4% W, 1.5% C, 1% Si, balance iron. Other interesting developments include the routine melting in vacuo of hydrogen-treated electrolytic iron into 5-lb. ingots 99.985% pure and the discovery that dissolved gases (mainly hydrogen) may be effectually removed from aluminum and magnesium alloys by bubbling nitrogen containing a small amount of CCl_4 through the melt.

F. P. GILLIGAN and J. J. CURRAN in *Iron Age*, May 19, correlate tests on very heavy gray iron hydraulic cylinders with tensile test bars cut from special castings ranging up to 10½ in. thick. The probable range of **STRENGTH OF GRAY IRON** is as follows:

Thickness of Casting	Upper Range	Lower Range
2 in.	28,000	21,000
4 in.	22,500	17,000
6 in.	20,000	15,000
8 in.	18,000	13,500
10 in.	16,000	12,500

Low silicon irons (Si about 1%) tend to fall along the upper range; higher silicon irons (Si about 2%) the lower, but as thickness increases the effect of composition is submerged. These figures are for cupola irons with up to 30% steel on the charge, and not for alloy or high test irons. The authors believe the effect of mass is not so marked in castings made of the latter varieties.

IN AN ADDRESS before the New York Chapter, A.S.S.T., printed in *Product Engineering* for June, W. E. BLEWETT discussed "Materials in Ships," and described six structural steels now available with higher tensile properties

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than the conventional mild steel. Some of them, like "martinel" (see METAL PROGRESS for August 1931) have the elastic limit raised and stabilized by controlling the temperature of the last pass and the cooling rate. The others depend largely on an increase in the carbon, manganese, or silicon content, with or without further additions of nickel, vanadium, or copper. It would appear, however, that these high strength **SHIP STEELS** have been used by American yards only to a limited extent. Large hull forgings, requiring fire welds, are made of 0.08 to 0.15% carbon steel, and may be counted upon to develop 30,000 elastic limit and 40% elongation. Small hull forgings like stanchions have 0.15 to 0.20% carbon and develop 32,500 elastic limit (5 to 10% more if normalized). Heavy steam engine forgings for merchant ships are of 0.20 to 0.30% carbon steel; forgings are usually heat treated to 40,000 lb. per sq.in. elastic and 30% elongation. Carbon-vanadium forgings (normalized and drawn) developing 60,000 elastic limit and 27% elongation are favored for hydraulic work and diesel engine parts. Naval specifications for main shafting call for 3½% nickel steel, carbon 0.30 to 0.40%, which tests at 50,000 to 65,000 lb. per sq.in. elastic limit and an elongation of 25 to 30%; it also has superior impact strength and corrosion resistance.

STUDIES made at Woolwich Arsenal were reported to the British Iron & Steel Institute in May on **POROSITY OF TIN PLATE.** Perforations are permanently marked as follows: First the sample is cleaned by washing in CCl_4 and then in a beaker containing a little acetone. The beaker is closed by a bottle containing cold water, warmed and the acetone vapor condensing thereon showers the sample below. In about 10 min. metal should be free of grease, as determined by dipping into distilled water and seeing whether the water film breaks. This distilled water must be of high purity, neutral or slightly acid in reaction (5 drops of methyl red indicator should color 10 c.c. slightly pink). A clean beaker filled with it and

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containing the cleaned tin plate is held at 205° F. for 3 hr., then cooled and stored for 18 hr. Adherent reddish brown spots with black nuclei form on the previously bright surface. Tin plate having 1½ lb. tin per base box may have 7 to 22 pores per sq.cm.; these numbers drop to 1 to 3 for 5-lb. tin plate. The paper also details a recommended procedure for applying paper, dampened with ferricyanide solution, which will give identical results.

NITRIDE hardening of centrifugally cast cylinder liners was described by J. E. HURST before the British Iron & Steel Institute's May meeting. The annealed metal (called "Nitricastiron"), which analyzed 2.60% total carbon, 1.20% combined carbon, 2.60% silicon, 0.60% manganese, 1.70% chromium, and 1.40% aluminum, was melted in an oil-fired crucible furnace (aluminum added to the melt as ingot) and cast in a permanent mold. The castings air harden, so they were first annealed and slowly cooled. After rough machining the castings are oil quenched from 1600° F. and tempered for several hours at 1150° F. Liners finished to size are then cleaned and the **CAST IRON NITRIDED** in the usual way for 90 hr. at 950° F. Diamond hardness is then about 975; no spalling is observed around the indentation. Under the microscope a lightly etched surface layer 0.001 in. thick is seen; this is marked with numerous small cavities where graphite formerly existed. Nitrides penetrate a depth of 0.010 in. The body of the metal contains some massive cementite, some very fine graphite, and a matrix which is presumably pearlite, although the constituents are not resolved at 1500 diameters.

FEATURES of the June meeting of the American Society for Testing Materials were two series of papers on steel castings. It illustrates the tempo of technical progress to say that the first American **STEEL CASTINGS** were made at Midvale 65 years ago, while at present about 300 plants comprise an industry having an an-

Valuable Publications offered by industry

Blast Gates—A new folder of W. S. Rockwell Co., tells the advantages of the company's line of air-tight blast gates and gives dimensions and other data. Bulletin RO-325.

Ammonia Dissociators—Ajax Electric Co., has a new bulletin describing the technical and economical advantages of producing hydrogen and nitrogen by dissociating anhydrous ammonia. Bulletin JU-83.

Low Power Microscope—Carl Zeiss, Inc., has prepared a booklet describing a new low power binocular microscope, magnifying 4 to 31 diameters, which is valuable in examining fractures, etc. Bulletin MIK-464e.

Rust Preventive—A recent publication of Dearborn Chemical Co., describes the well known rust preventive, No-Ox-Id, which is now offered as a paint foundation in the colors red, gray and black. Bulletin JU-36.

Manganese-Vanadium Cast Steels—Vanadium Corp. of America offers a reprint of discussion of effect of vanadium additions on properties of intermediate manganese steels containing 1.25 to 2% manganese. Bulletin JU-27.

Nickel Steel—International Nickel Co. is publishing a bi-monthly illustrated newspaper devoted exclusively to nickel alloy steels. Contains technical, semi-technical, and news articles dealing with the production, treatment, and uses of these steels as well as other special features. Bulletin JU-45.

Furnace Parts—Driver-Harris Co. has issued a bulletin featuring furnace parts made of their alloys. This bulletin gives data and advantages of Nichrome and Chromax heat resisting alloys in the form of furnace parts. Bulletin N-19.

Ingot Molds—Gathmann Engineering Co. The subject of ingot molding is covered in a new book on this subject. Numerous illustrations of the effect of various methods of finishing and casting on the reliability of steel products are given. Bulletin D-13.

Welding Electrodes and Accessories—General Electric Co. has a new bulletin which describes its line of welding supplies and accessories. Many illustrations. Bulletin J-60.

Conveyor Belt Handbook—Wickwire Spencer Steel Co. A new loose-leaf handbook, describing various types of metal conveyor belts for high and low temperatures. This includes the new heavy duty "Alpha" link belt, "Delta" plate belt and spiral type. Bulletin N-37.

Nitriding Steel—Properties of a new chromium-vanadium nitriding steel developed by Union Carbide & Carbon Research Laboratories are listed in a new publication of Electro Metallurgical Sales Co. MM-16.

Quenching—A new 80-page book, "Houghton on Quenching," containing over 30 charts and photomicrographs, has just been published by E. F. Houghton and Co. MM-38.

High Frequency Induction Furnaces—Ajax Electrothermic Corp. New bulletin gives detailed information regarding Ajax-Northrup high frequency induction furnaces operated from static converters, for laboratory use or for small-scale production. Bulletin JA-41.

Neutral Atmosphere which makes possible the hardening of high speed steel without scale, decarburization or carburization, is explained by the bulletin, "The Sentry Diamond Block Method of Hardening High Speed Steel," issued by the Sentry Co. MM-84.

Hy-Ten Alloy Steels—Wheelock, Lovejoy & Co., Inc. "Pertinent Points" folders covering physical properties, heat treatment and applications of all grades of Hy-Ten Special Steels. Bulletin D-22.

Furnaces for the Steel Industry—The Electric Furnace Co. have issued a four-page folder illustrating and listing several electric and fuel fired furnaces of various types they have installed in steel plants. Bulletin D-30.

Aluminum and Its Alloys—Aluminum Company of America has prepared the book "Alcoa Aluminum and Its Alloys" which presents data and tables on the physical and chemical properties of aluminum alloys. MM-54.

Machine Heat Treating—American Gas Furnace Co. A 16-page illustrated booklet giving information on the various types of conveyor heating machines available for heat treating on a production basis. Bulletin D-11.

Thermocouple Heads—Leeds & Northrup Co. offer a folder descriptive of their new Universal thermocouple heads. Photographs show simplicity of installation. Bulletin M-46.

Heat and Corrosion Resistant Alloys—General Alloys Co. A new bulletin is available on chrome-nickel and straight chrome heat and corrosion resisting alloys. Bulletin D-17.

Peroxygen Compounds—A 24-page booklet issued by Roessler & Hasslacher Chemical Co. presents briefly the characteristics and uses of a number of peroxygen compounds. Bulletin M-29.

Welded Pipe—Republic Steel Corp. has prepared a booklet on its electric weld line pipe and casing. Manufacturing processes and performance data are presented. Bulletin AA-8.

Hardness Testing—Pamphlets are available from Shore Instrument Co. describing the Monotron and Scleroscope hardness testing machines. Bulletin J-33.

Recuperators—Carborundum Co. The complete story of Carborundum Co. recuperators for industrial furnaces, describing the type and covering operating conditions. Bulletin F-57.

Chromel Couples—Hoskins Manufacturing Co. Bulletin contains technical data on pyrometer couples. Bulletin M-24.

Welding Electrodes—Metal & Thermit Corp. has published a folder outlining the advantages of Murex mineral coated welding electrodes. Several types of electrodes are described. MM-64.

Micro-Metallograph—E. Leitz, Inc. A precision instrument for making accurate photomicrographs without distortion and with absolute flatness of field is described. Bulletin M-47.

"Carbonol Process for Carburizing Steels" is the title of the new 12-page bulletin published by the Hevi-Duty Electric Co. The bulletin describes the results and advantages of the Carbonol process of carburizing. Bulletin N-44.

Wear and Lubricant Tester—Timken Roller Bearing Co. has prepared a description of a new machine for testing load carrying capacity of lubricants, measuring friction and wear of materials. Bulletin M-71.

Ferro-Carbon Titanium—An illustrated 111-page catalog technically describing this alloy and its use in steel for forgings, steel castings, rail steel, sheets, plates, etc., is offered by Titanium Alloy Mfg. Co. Bulletin J-90.

Metal Progress, 7016 Euclid Ave., Cleveland.

Please have sent to me the following literature as described under "Industrial Publications" in the July issue of METAL PROGRESS. (Please order by number.)

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nual capacity of about 2,000,000 tons. Practically all of the production is heat treated and ⅛ of it is alloy steel. Sizes and required properties are exceedingly diverse; R. A. Bull abstracted no less than 29 important American specifications! Fred Grotts described a number of medium-carbon low-alloy cast steels having pearlitic microstructures when normalized. In regular production they develop 100,000 lb. per sq.in. ultimate strength, 40% reduction of area, and 26 ft-lb. Izod impact. In these steels manganese is increased beyond the normal content to the regions represented by 1.20%, 1.45%, 1.85%, and 2.5%; especially in the higher manganese range these steels lack toughness when fully annealed (although the impact values are strikingly increased by a small amount of vanadium, molybdenum, or zirconium). It is therefore recommended that they be air cooled and drawn. Somewhat less than these properties can be had with ordinary 0.30 to 0.40% carbon cast steel plus fractional percentages of molybdenum, vanadium, or chromium.

Devices for burning light hydrocarbons, which ordinarily produce non-luminous flames are described briefly by W. Trinks in *Heat Treating & Forging* for May. To burn with luminosity, regarded as necessary for radiant heating, the gas must be cracked into free carbon by heat before it mixes with much oxygen. This operation is the easier the heavier the gas (i.e., methane, butane, and ethane are successively less difficult) the higher the temperature, and the longer the time. Since the action cannot be predicted by theory, it is recommended that experimental installations be supplied with two burners, one for a light and one for a heavy gas. Carbon will build up on hot walls bathed by uncracked gas; the burner and auxiliary air ports must therefore be designed so that uncracked gas is surrounded by air streams. Gradual intermingling of the gas core and air sheath in these streams gives the name **DIFFUSION COMBUSTION**. A "diffusion burner" usually consists of a series of parallel alloy tubes, long

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as compared to their diameter, through which the gas plus a very little air is blown. Combustion air surrounds these tubes and is blown in the same direction. When operating properly, the alloy tubes are hot enough from the furnace heat to crack the heaviest constituents in the gases. Entering the furnace these streamlets of gas are entirely surrounded with air; if the flow is not turbulent these diffuse into each other gradually, but not before the most of the gas has been cracked by the furnace heat. Diffusion and combustion should, of course, be complete by the time the outlet flue is reached; sometimes to insure this, turbulence must be introduced by baffling or otherwise partway down the furnace. Many luminous-flame installations heat the cold furnace slowly and with excessive smoking.

A GOOD bearing should be strong, plastic, and smooth at the operating temperature; it (rather than the shaft) should take the unavoidable wear; it should be in tight contact with its backing and diffuse heat rapidly; it should be sound and easily workable. These diverse requirements have been met by alloys of complex structure, having hard crystals in a softer matrix. LELAND E. GRANT describes how **TIN-BASE BABBITTS** fit the requirements in June *Metals & Alloys*. It would appear that a centrifugally cast babbitt is improved with high temperature of pouring and high temperature of backing — the slower solidification permits larger crystals of the hardest constituent to grow. While most specifications sharply limit the amount of lead, it is probable that it increases hardness and malleability up to at least 2.5%, and is of no harm except in bearings which run hot enough to endanger even a lead-free babbitt. Nickel, a once-recommended improver, is no longer used in railroad bearings. A small amount of bismuth reduces the melting point of the matrix and causes local fusion or wiping while running in. For high pressure and speeds 90 Sn, 7 Sb, 3 Cu or 93 Sn, 3.5 Sb, and 3.5 Cu (somewhat softer and tougher) are rec-

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ommended. Five analyses are used for automobile engines — undoubtedly no such range would be required if impurities and casting conditions were adequately controlled. One highly recommended is S.A.E. No. 11: 86 Sn, 7 Sb, 6 Cu. An important point is to finish the bearings with a diamond tool or an accurate broach; this gives 75% bearing contact, avoids hand fitting and slow running in.

MANUFACTURING methods for Carboloy tools are described by ADAM MACKENZIE in June *Machinery*. They follow the methods described in Mr. HARDY's article in this issue; it is important that the mixture of powdered carbides and metallic binder be ground in a ball mill. After pressing, the slugs of **HARD CARBIDES** are "semi-sintered" by heating to about 1550° F., whereupon they can be sawed and trimmed into correct shape about as easily as chalk. Final sintering is also done in pure hydrogen at 2450 to 2800° F., and causes a shrinkage of about 15% in all dimensions, which is provided for, so that expensive grinding to final shape may be minimized. These hard tips are then carefully fitted into recesses cut into a tool steel shank and brazed (or rather "coppered") in place by heating in a hydrogen-nitrogen atmosphere above the melting point of the copper slipped into the joint.

WHEN welding the 18-8 stainless steels the weld (even though it is of correct composition) and a portion thereto has lost whatever advantage the rest of the piece may have acquired by previous heat treatment and cold work, and this region is surrounded by metal containing microscopic precipitated carbides, a well-known indication of corrodibility. In a spot weld this annular portion is called the "corona" by E. J. W. RAGSDALE in a paper on "Stainless Steel in Aircraft Construction" read before the June meeting of the A.S.M.E. in Buffalo. Since stainless steel is favorable to spot

welding — the surfaces are free of oxide and the electrical resistance is 10 times that of mild steel — and since the size of the corona seems to be due to time and current, the Budd company's new **SHOT WELDING** process uses equipment which rigidly controls the latter factors. Proper conditions are set on the machine by a supervisor. Any variation from this standard causes a bell to ring continuously. An automatic recorder marks down a line for each spot weld proportional to C^2r (or heat input) and the time. A single weld in two pieces of 0.012-in. sheet requires only 0.035 B.t.u. Spots should be about 3 times the diameter of the total thickness joined; flanges should be 3 spot diameters in width, this reducing the outstanding legs which are weak against buckling, but eliminating any danger that the edges, where fatigue cracks start, may be damaged by the joining operations.

MANY proposals to substitute molybdenum for tungsten in high speed steels, either in whole or in part, have been made in the past, but the alloys have not been vigorously commercialized, probably because they did not promise sufficient advantages over the somewhat standardized analyses to warrant the expense. In order to develop this so-called strategic metal, much work has been done on the **MOLYBDENUM HIGH SPEED** steels at Watertown Arsenal with gratifying results. According to *Iron Age*, June 9, Universal Steel Co. and Cyclops Steel Co. are now marketing a "Motung" tool steel, wherein part of the required tungsten is replaced. Microstructure, heat treatment, fabrication, speeds, and feeds are all comparable to 18–4–1 high speed steel. Heat treatment is at somewhat lower temperatures — hardening is done from 2175° F., and maximum secondary hardness appears at 1015° F. To avoid soft skin, due to depletion of carbon and molybdenum, the bars should be sprinkled with borax before heating. Tools heated in salt baths, in controlled gas atmospheres, or box annealed with carbonaceous filling are also said to retain surface hardness.

Powdered metal

for consolidation goes up proportionately to enormous figures. Furthermore, the depth of the mold (in relation to its width) must not be too large else the fine material has a tendency to bridge from side to side and the resulting pellet has loose, unconsolidated centers. Clearances between dies and plungers must be less than the diameter of the smallest particles, or powder will squirt out the clearance. It may be said, however, on the basis of experience gained in commercial production of hundreds of thousands of parts, that these limitations now offer no serious trouble up to 6 in. diameter and the same depth.

Can Be Sprayed or Painted

Finally, it may be mentioned that powdered metal has been sprayed or painted on surfaces with an easily combustible hydrocarbon and then processed in various ways. A recently developed welding rod, made of 1½% manganese steel with powdered nickel sprayed on the surface, may be cited. Powdered chromium, used as a mold wash, gives cast iron with a hard corrosion-resisting skin. Zinc or other corrosion-resisting metal has been sprayed on steel sheet, then heat treated to burn off the binder and weld the particles together and to the base metal, and the whole thing rolled to consolidate and smooth the coating.

It may conservatively be estimated that the present rate of consumption of powdered metal for synthetic alloying and manufacture of pressed parts is on the order of 100 tons per month. It is true that the powdered metals sell at a considerable premium over the purest varieties in ingot form, but nevertheless the articles made are selling at a competitive price. Since new uses are being added continually, and the consumption correspondingly increasing, the production of metal powders at still lower prices is only a question of time. Every cent per pound reduction will increase the field of application enormously.